

**CH146 GRIFFON DIRECT VOICE INPUT CONTROL
FOR THE CANADIAN FORCES
UTILITY TACTICAL TRANSPORT HELICOPTER**

FINAL PROJECT REPORT

31 August 2000

Contract Serial No. W8477-8-AC40/003/SV

Prepared by

BAE SYSTEMS CANADA INC.

AEROSPACE
HUMAN FACTORS ENGINEERING
415 LEGGET DRIVE
KANATA, ONTARIO
K2K 2B2

BAE SYSTEMS

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EXECUTIVE SUMMARY

The Canadian Forces Utility Tactical Transport Helicopter is a modern land aviation aircraft which is used in numerous complex roles. The core of the CH146 Griffon avionics system architecture is a BAE SYSTEMS CANADA INC. (BSC) Control and Display Unit (CDU). The location and method of operation of the CDU requires extended head-down operation by the pilot in some circumstances, which has been found to have flight safety implications in the tactical helicopter environment, particularly in bad weather or when using Night Vision Goggles (NVGs). One technology that shows substantial promise to address this issue is Direct Voice Input (DVI). DVI permits the control of equipment using voice commands, and has the potential to greatly reduce the amount of time that the pilot has to direct his visual attention to controls and displays in the cockpit.

BSC was tasked by the Defence and Civil Institute of Environmental Medicine (DCIEM) to develop an operationally suitable Operator Interface (OI) for the CH146 Griffon. Additionally, BSC was to perform, in conjunction with the National Research Council (NRC), an assessment of a speech recognition system during operational type missions in a Bell 412 helicopter.

An OI (syntax and feedback) was developed. A literature review and site visits to DVI research facilities provided the foundation for the OI development. This knowledge was supplemented with information about the Griffon operational environment provided by domain experts and a site visit to Canadian Forces Base Gagetown. Both the vocabulary and command structure were developed through role-playing exercises, attempting to mimic the current interaction between pilots. The proposed feedback is an audio-alerting tone supplemented by a small text-based display.

A usability evaluation of the OI was performed in the BSC Aircraft Crewstation Demonstrator (ACD). Two experiments were conducted comparing the existing cockpit configuration with a DVI-equipped cockpit. In each experiment, six two-member crews, each consisting of a Flying Pilot (FP) and a Non-Flying Pilot (NFP), flew through a series of missions. In the first experiment, subjective evaluations of both cockpit configurations were obtained from the FP and NFP. In addition, an objective measure of crew behaviour was obtained by using head-tracking apparatus to record the head positions of the FP and the NFP throughout the missions. The second experiment assessed the attentional demands placed on the FP and NFP in the DVI versus the existing configuration.

Pilots indicated that the DVI system reduced the workload of the NFP and reduced the amount of time that the NFP was required to look down into the cockpit. Objective measures of behaviour confirmed these subjective reports. In particular, relative to the current configuration, DVI was shown to substantially reduce the NFP head-down time. This resulted in faster and more accurate detection of visual targets in the external scene for the NFP. It was concluded that a DVI system would have the potential to enhance flight safety and mission performance for crew in the CH146 Griffon. The results of the present evaluation also showed that the FPs allocated attention toward the DVI system. Allocation of attention toward the DVI system provides the FP with additional information relating to aircraft systems, but may have a negative impact on the FPs performance on other tasks. Generally, the combination of auditory

tones and visual feedback of the commands was judged to be effective. The pilots in the OI study were able to remember and use the set of DVI commands effectively. Several pilots noted that a DVI system would be especially useful when NVGs are used in the Griffon.

A commercially available speech recognizer was installed in the NRC Bell 412 helicopter to assess system performance under ambient helicopter noise. The syntax and methodology were drawn from work performed by the United States Air Force Research Laboratory to allow a comparison of the results of this study with previous research. Participants flew the helicopter under four flight profiles while reading prompts into the speech recognizer from a small liquid crystal display mounted under the glare shield. Six participants, five of whom had previous experience with the speech recognizer through evaluations at DCIEM and BSC, took part in the study. The overall phrase error rate for the system was 6.4%. Initial review of the data suggests that the error rate is biased by the performance achieved by the individual with no previous DVI experience, i.e. his error rate is substantially greater than any of the other individuals involved, inflating the overall phrase error rate. Further analysis of the results by Mr. Carl Swail of the NRC is expected later this fall, but these results suggest that commercial speech recognition technology is sufficiently robust to function in a challenging environment such as a helicopter cockpit.

Further research addressing the human factors issues of incorporating DVI in a cockpit needs to be conducted in support of a pre-production development effort. Research should be conducted to understand the interaction between the FP and the DVI system in both the modified Crew Resource Management (CRM) implemented in the OI evaluation and the current Griffon CRM. Alternative feedback methods, particularly voice feedback, should be explored. The addition of new commands to accommodate additional cockpit functions or provide alternatives to existing commands should be considered. To support the pre-production system development, alternate speech recognizers should be assessed in the challenging helicopter environment to select the technology best suited to the application.

Sommaire

L'hélicoptère utilitaire de transport tactique des Forces canadiennes est un appareil moderne qui sert à l'armée de terre dans de nombreuses missions complexes. Le panneau de commande et d'affichage (CDU) produit par BAE SYSTEMS CANADA INC. (BSC) est le cœur de l'architecture du système avionique du CH146 Griffon. Compte tenu de l'emplacement et des méthodes de fonctionnement du CDU, le pilote est forcé dans certaines circonstances de garder la tête baissée pendant des périodes prolongées, ce qui peut avoir des répercussions sur la sécurité des vols dans le milieu opérationnel des hélicoptères tactiques, notamment par mauvais temps et en cas d'utilisation de lunettes de visions nocturne (LVN). Pour régler ce problème, la commande vocale directe (CVD) est une technique qui s'annonce très prometteuse. La CVD permet de faire fonctionner l'équipement grâce à la voix, et elle a tout pour faire diminuer grandement le temps que le pilote doit consacrer à consulter de visu les commandes et les écrans du poste de pilotage.

L'Institut de médecine environnementale pour la défense (IMED) a chargé BSC de mettre au point une interface utilisateur (IU) adaptée aux opérations du CH146 Griffon. De plus, BSC devait effectuer, de concert avec le Conseil national de recherches du Canada (CNRC), l'évaluation d'un dispositif de reconnaissance de la voix pendant des missions de type opérationnel à bord d'un hélicoptère Bell 412.

Une IU (syntaxe et rétroaction) a été élaborée. Une analyse documentaire ainsi que des visites de laboratoires de recherches en CVD ont servi de base à la mise au point de l'IU. Le moyen de rétroaction envisagé fait appel à une tonalité d'avertissement audio complétée par un petit afficheur alphanumérique.

Deux expériences ont été menées dans la maquette d'essai de poste d'équipage de BSC, ce qui a permis de comparer la configuration actuelle du poste de pilotage avec celle d'un poste de pilotage équipé d'une CVD.

Des données tant subjectives qu'objectives ont montré que la CVD réduisait la charge de travail du pilote n'étant pas aux commandes (NFP) et entraînait une réduction du temps que celui-ci devait passer à regarder à l'intérieur du poste de pilotage. Les résultats ont également montré que l'attention que consacrait le pilote aux commandes (FP) à la CVD, bien que lui donnant des renseignements supplémentaires sur divers systèmes de l'appareil, avait un impact négatif sur l'exécution des autres tâches du FP. Il a été finalement établi qu'une CVD avait le potentiel pour augmenter la sécurité des vols et le rendement en mission des équipages de CH146 Griffon.

Un système de reconnaissance de la parole Verbex™ a été installé à bord de l'hélicoptère Bell 412 du CNRC afin d'évaluer le rendement du système dans les conditions de bruit qui règnent à l'intérieur d'un hélicoptère. Les participants ont suivi quatre profils de vol tout en lisant dans le système de reconnaissance de la parole des messages qui apparaissaient dans un petit afficheur à cristaux liquides monté sous le pare-soleil. Le taux d'erreur général du système de reconnaissance a été de 6,4 %.

Il serait judicieux d'effectuer d'autres recherches portant sur les questions liées aux facteurs humains si l'on veut comprendre l'interaction entre le FP et la CVD, tant dans la

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gestion des ressources de l'équipage (CRM) modifiée aux fins de l'évaluation de l'IU que dans la CRM actuelle du Griffon. D'autres méthodes de rétroaction devraient être explorées, tout comme l'optimisation de la syntaxe. Pour aider à la mise au point du dispositif de présérie, d'autres systèmes de reconnaissance de la parole devraient être évalués dans l'environnement très contraignant des hélicoptères afin de choisir la technique la mieux adaptée au but visé.

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SECTION ONE – INTRODUCTION

1.1 BACKGROUND

The Canadian Forces (CF) Utility Tactical Transport Helicopter (UTTH) is a modern land aviation aircraft which is used in numerous complex roles. The core of the CH146 Griffon avionics system architecture is a BAE SYSTEMS CANADA INC. (BSC) (formerly Canadian Marconi Company (CMC)) Control and Display Unit (CDU). The location and method of operation of the CDU requires extended head-down operation by the pilot in some circumstances, which has been found to have flight safety implications in the tactical helicopter environment, particularly in bad weather or when using Night Vision Goggles (NVGs).

One technology that shows substantial promise to address this issue is Direct Voice Input (DVI). DVI has the potential to greatly reduce the amount of time that the pilot has to direct his visual attention to controls and displays in the cockpit by allowing him/her to control the CDUs and other cockpit controls via voice commands. In high workload applications where the crew's attention must be directed outside the cockpit, DVI has the potential not only to improve mission effectiveness, but also to improve operational mission safety margins. Performance improvements are anticipated, particularly when crewmembers are required to maintain an "eyes-out, hands-on-stick" posture.

1.2 AIM

This aim of this project is to develop and evaluate an operationally suitable DVI Operator Interface (OI) for the Griffon.

1.3 SCOPE

This report addresses the items described in the following subparagraphs:

- a. the syntax and feedback development;
- b. OI evaluation; and
- c. aircraft based assessment of a Commercial Off-The-Shelf (COTS) speech recognition system.

1.4 REPORT OUTLINE

This report documents the work performed throughout the project, namely the development and evaluation of an OI and flight trials assessing COTS recognition technology. This report consists of the following sections:

- a. **Section One—Introduction.** Section One provides introductory information including background, aim, scope and a report outline.

- b. **Section Two—OI Development.** Section Two describes the methodology and activities undertaken during the syntax and feedback development.
- c. **Section Three—OI Evaluation.** Section Three describes the assessment of the OI conducted in the BSC Aircraft Crewstation Demonstrator (ACD). This section was prepared as a standalone document by members of the Centre for Applied Cognitive Research at Carleton University. The conclusions drawn in this section are included in Section Five for completeness.
- d. **Section Four—Flight Trials.** Section Four describes the trials conducted with the Flight Research Laboratory (FRL) of the National Research Council (NRC) to assess performance of COTS recognition technology in a helicopter environment.
- e. **Section Five—Conclusions and Recommendations.** Section Five summarizes the findings discussed in the report.
- f. **Section Six—References.** Section Six documents references used in the report.
- g. **Annexes.** This report includes the following annexes:
 - (1) Annex A—Glossary of Terms and Acronyms,
 - (2) Annex B—Site Visit Reports,
 - (3) Annex C—Literature Summary,
 - (4) Annex D—Composite Mission Scenario,
 - (5) Annex E—DVI OI Specification,
 - (6) Annex F—Manual Input (MI) Trial Questionnaire,
 - (7) Annex G—DVI OI Evaluation Voice Input Trial Questionnaire,
 - (8) Annex H—DVI OI Trials Final Questionnaire,
 - (9) Annex I—"MAGIK" Script for DVI OI Evaluation,
 - (10) Annex J—"ZERO" Script for DVI OI Evaluation,
 - (11) Annex K—Ethic Committee Application, Informed Consent and Debriefing Form,
 - (12) Annex L—Mission Briefs and Maps,

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- (13) Annex M—Questionnaire Rating Scale Results,
- (14) Annex N—Written Responses to Questionnaires, and
- (15) Annex O—Event Cut-off Times.

SECTION TWO – OPERATOR INTERFACE DEVELOPMENT

2.1 DEVELOPMENT METHODOLOGY

The initial step in the OI development was to gain an appreciation of the issues that might be encountered during the design phase. This was accomplished through a literature review and site visits. Site visits were conducted to DVI research facilities at DERA and an operational CH 146 Griffon unit at Canadian Forces Base (CFB) Gagetown. A composite mission scenario was developed based on the data collected during the CFB Gagetown site visit. The composite mission scenario was used in conjunction with video tapes of operational missions and domain expert knowledge to identify tasks suitable for DVI implementation. Several system models were identified during the initial phase of the design effort. The model selected to guide the development can be described as 4th crewmember, mid-level approach. A role-playing exercise, in which the domain expert played the role of the Flying Pilot (FP) while other members played the role of a novice Non-Flying Pilot (NFP), was used to generate the vocabulary and structure for the DVI commands. The content of DVI feedback was identified during the role-playing exercise; however, the method and structure was not determined until the syntax development was complete. Alternative feedback methods were identified and the merits of each assessed. To maximize the benefit of hands-free control in the cockpit, the current CRM model was modified to allow the FP to control aspects of the CDU while maintaining Hands-On Cyclic And Collective (HOCAC).

2.2 PRELIMINARY WORK

2.2.1 General

Before embarking on the syntax and feedback development effort, the need for a thorough understanding of potential issues that might be encountered during the development was identified. Recent research in DVI, particularly relating to syntax and feedback design, was felt to be essential to the development exercise. It was also believed that data characterizing the operational environment was needed. Site visits and a literature review were used to develop the knowledge necessary for the project.

2.2.2 Site Visits

Site visits were conducted by the DVI team to further the understanding of issues related to the Griffon DVI development.

Team members visited an operational Griffon unit at CFB Gagetown to gain knowledge of the operational environment. Several high workload missions were observed and video-recorded for further analysis.

A site visit to DERA in the United Kingdom (UK) was conducted to facilitate an information exchange regarding current research in DVI. DERA is a world-class facility conducting research in diverse fields ranging from operational analysis to weapons systems to ergonomics, primarily for the UK Department of Defence. Of particular interest to the DVI team

was research being conducted in speech recognition algorithms, the integration of speech recognition systems in aircraft, and interface development for speech recognition systems. This required visits to two DERA locations. The first visit was to the Centre for Human Sciences (CHS) at DERA Farnborough, where investigations into the human factors issues related to DVI are being conducted. The second DERA site visited was DERA Malvern, where research focused on the development of recognition algorithms and hardware. Both visits yielded promising information regarding the successful integration of the technology within an aircraft environment; however, it became clear that little formal research had been conducted by DERA concerning the development of syntax and feedback for such a system.

Unfortunately, the prototyping cycle did not afford the opportunity to conduct the planned site visit to Wright-Patterson Air Force Base (WPAFB). However, it was possible to visit the Air Force Research Laboratory (AFRL) after the experimental work was completed. The results of this project were presented and information received about their ongoing work. A significant project at WPAFB is the development of techniques to supplement traditional speech recognition algorithms. The techniques are based on models of human speech production and perception, and may improve recognition accuracy in fielded systems as the technology matures.

A summary for each of the site visits can be found in Annex B.

2.2.3 Literature Review

A literature review was conducted to gain a better understanding of the current state of DVI research. Unfortunately, little research was available that was directly relevant to the design of an aircraft-based syntax. The published papers fell into two broad categories: interface design projects and recognition rate studies. The majority of papers in the interface design category addressed issues specific to telephony and desktop computer domains; however, two papers discussed the development of a syntax for the CH146 Griffon. These papers addressed only the development of the syntax and no results were available to indicate its usability. The recognition rate studies reported in the literature, while largely based in aircraft environments, focused on speech recognition technologies and recognition accuracy. A summary of each paper is included in Annex C.

2.2.4 Composite Mission Scenario

Several high workload mission segments were identified based on data collected during the site visit to CFB Gagetown. The segments were selected in consultation with Subject Matter Experts (SMEs) to encompass the unique activities associated with defined Griffon missions while avoiding repetition as much as possible. These mission segments were concatenated to form a single mission scenario. A great deal of latitude is required, however, to write a single scenario to encompass all of the activities which may occur. In this regard, the complexity of the scenario strays from reality to minimize any requirement for multiple scenarios to a minimum. The mission scenario is contained in Annex D.

2.3 SYNTAX DEVELOPMENT

As the iterative design of the syntax began, it became quickly apparent that several design philosophies existed. It was identified that whichever approach was selected, it would have significant implications for the syntax development. The approaches are outlined in Figure 2-1.

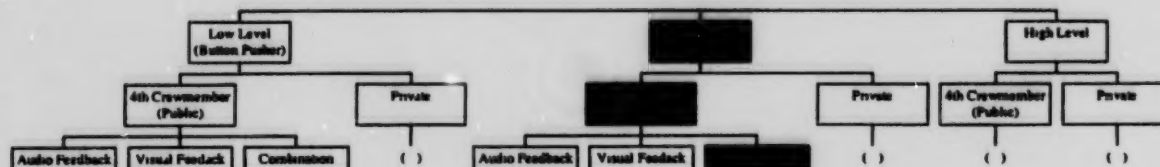


Figure 2-1 Possible Design Approaches for a DVI System

The first decision made concerned the nature of the system. A low-level, or "button-pusher," approach would simply replace all of the keypresses of the current system with corresponding voice tokens. As this method is a direct mapping of the existing interaction from one input modality to another, it would be readily understood by the user community. Alternative approaches, allowing users to interact with the system at a mid- or high-level, would provide users' the ability manipulate cockpit systems in ways which are currently unavailable to them. These levels represent user mental models of the system, which while not directly visible to an observer, can be captured through studying cockpit communications. A mid-level model is illustrated in the example of a Flying Pilot (FP) asking the Non-Flying Pilot (NFP) to contact "Ottawa Tower." In the current cockpit, the NFP must translate the FP's request of "Ottawa Tower" to the low-level keypresses, e.g. "118.1" required to establish the radio link, and manipulate the CDU pages to enter the data and establish the radio link. It would appear that allowing pilots to interact with the system at a mid- or high-level will reduce the workload, as users will not have to translate their model of the system to a representation understood by the CDU. However, the potential increase in complexity and vocabulary associated with mid- or high-level commands may offset the reduction in workload gained through the elimination of the translation process. Also to be decided was if all lower level functionality should be included if a mid- or high-level approach was selected, e.g. if a high-level approach was chosen, should the user be able to interact with the system at the mid- and/or low-levels? This has implications for error correction and the vocabulary size, and as a result, operator workload. The potential workload resulting from error correction is of particular concern if the DVI system allows users to manipulate the system at more than one level. The workload imposed during error correction is increased by multiple levels of interaction, as the user must determine which level provides the most effective means to correct the error, adding a troubleshooting and decision making task to the existing memory load. Based on analysis of the cockpit, it was determined that a DVI system would provide the greatest benefit if it allowed users to interact at both the low- and mid-levels.

The next issue to be addressed was the inter-audibility of the system; i.e. should Pilot A hear all of the commands that Pilot B is issuing to the system? In the proposed private model, only the crewmember issuing the command would hear the command and receive the corresponding feedback. In the Griffon, which has a great deal of radio and intercom traffic, this has significant merit. However, because of the need for a common understanding of system

states (e.g. radio settings, navigation aids) between crewmembers, there is an advantage to a public system, where all individuals hear all commands issued to the system (and possibly receive all of the feedback). Consequently, a public system model was initially selected.

Three feedback approaches were considered: audio (either speech or tones), visual (lights or text displays), or some combination of the two. The issues related to feedback method selection are discussed in Subsection 2.4.

2.3.1 Task Identification

Analysis of video data collected during the site visit to CFB Gagetown, supplemented by Aircraft Operating Instructions (AOIs) and domain expert knowledge, was used to generate a list of cockpit tasks. The master list consisted of approximately 275 tasks. While the majority of tasks were based around the CDU, other cockpit tasks, such as controlling the windshield wipers or landing lights, were considered. Based on domain expert knowledge and human factors considerations, not all of the identified tasks were deemed suitable for implementation with DVI. The reduction of the task list from the master list to that which was implemented is illustrated in Figure 2-2. The initial reduction was based primarily on policy and safety issues, i.e. release of weapons, flight safety. Further reductions were made based on frequency of use, task complexity and the potential impact on workload.

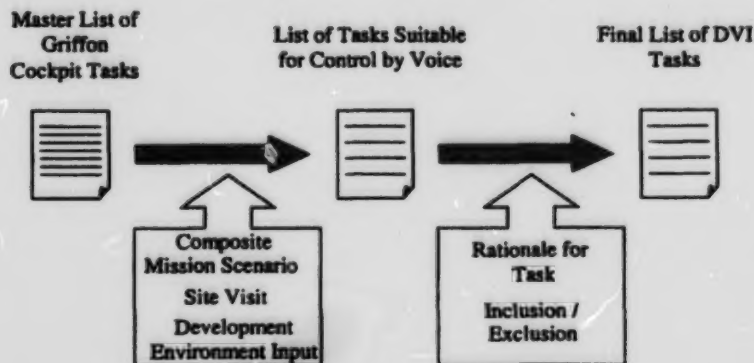


Figure 2-2 Selection of Tasks for Direct Voice Input

2.3.2 Role-Playing Exercise

After identifying the most probable DVI tasks, the structure and vocabulary to be used were developed. The fourth crewmember interface was intended to mimic the current interaction between crewmembers. To generate such an interface, the design team role-played situations where the FP asks an inexperienced NFP to perform cockpit tasks. The role of the FP was assumed by the domain expert, while other team members played the role of the NFP. The language and command structure used by the FP when asking the NFP to complete a task was recorded. In most cases, the FP did not issue commands in CDU format but rather in everyday English. As an example, when requesting that the NFP change a radio frequency, the FP would

ask for "Gagetown Tower" rather than "118.1"(the frequency). The NFP would then look up the corresponding frequency for Gagetown tower and enter it manually on the Comm Summary page of the CDU. In some cases, the command provided by the FP was ambiguous or inaccurate and the NFP would request clarification from the FP. These interactions were modelled using flowcharting tools. A sample interaction is shown in Figure 2-3.

2.3.3 Command Structure

As the design team worked through several examples, a pattern began to emerge in the structure of the FP requests. In the majority of the cases, the first word in the command was a verb or "action." This was generally followed by the "target" – the system or object to be manipulated. Finally, the data required to manipulate the target was provided. This yielded a consistent yet natural structure: <action> <target> <parameter>. A comparison with the command structures developed by Farrell *et. al* [Reference 1], reveals similar elements in their attempt to develop a syntax for controlling the CDU, however the ordering of the elements differs. The new structure was then applied to the remaining tasks to complete the syntax. This structure was suitable for the majority of cockpit tasks; however, in some instances it was determined that either the target or parameter was implied and not a required element of the command.

Some tasks that were initially identified as poor candidates for DVI were later implemented in the DVI syntax for completeness or consistency. A complete listing of the syntax is contained in Annex E.

The calculation functionality of the CDU was deemed suitable for DVI implementation; however, the implementation of these commands departs from the <action><target><parameter> model. Because of the number of parameters required for each calculation, it was felt that operator workload to recollect the required parameters in the prescribed order would be too great. Consequently, the calculation functions were modelled in a slightly different approach. The <action><target> model was maintained, but users were prompted by the system to provide the required parameters (in serial). These commands are also included in Annex E.

2.3.4 System Activation/De-Activation

The focus of this project was to develop the syntax independent of the system used during the implementation phase. However, there was one implementation issue believed to be common to any anticipated solution: how does the system distinguish between normal cockpit communication and DVI commands? Three options were identified: a Push-To-Talk (PTT) switch, which would be depressed and held while each DVI command was issued; keyword activation, where specific words or phrases are spoken to put the system in and out of listening mode; or "always listening," where the system attempts to recognize all voice input. Because of fears of inadvertent command execution, it was determined that an "always listening" system was not appropriate for this application. The remaining two options were considered at length.

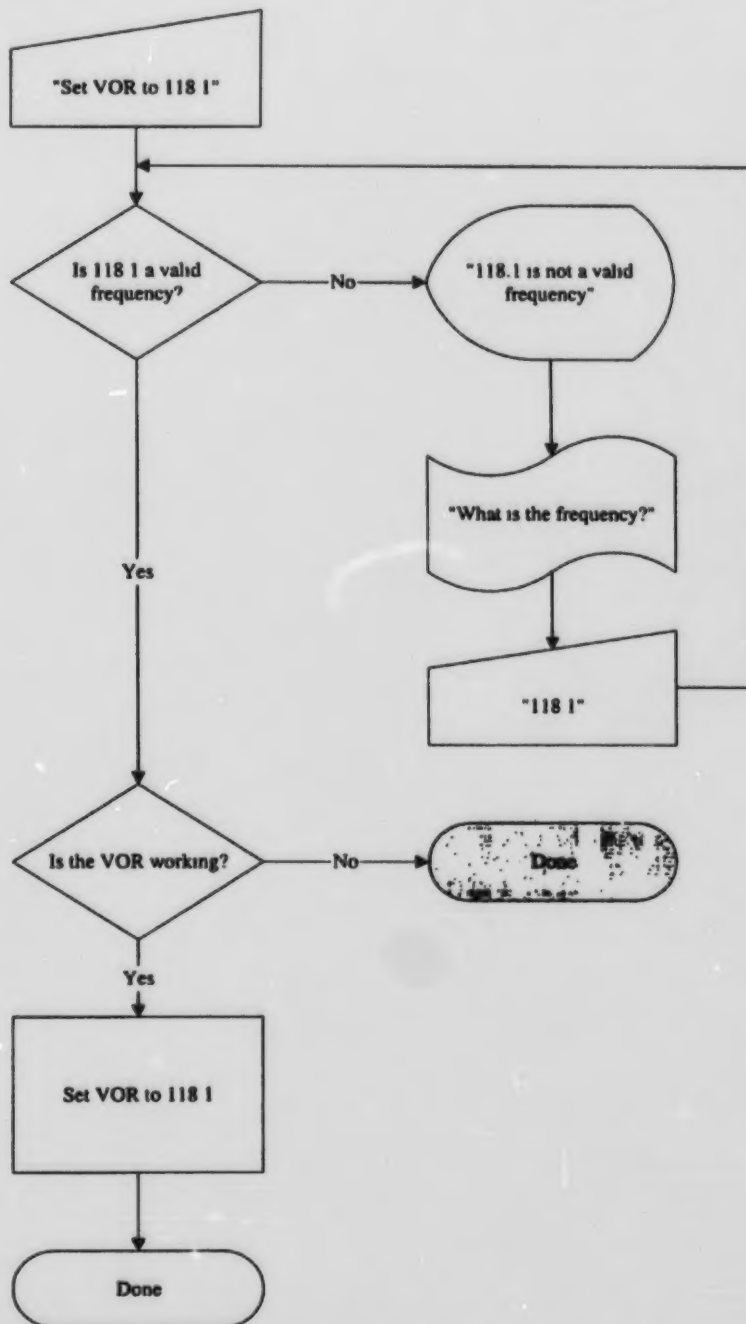


Figure 2-3 Sample "Dialogue" Between Two Crewmembers

A PTT system would require the user to depress a switch and hold it while speaking a DVI command. This has merit, as it is consistent with the manner in which external communications are conducted. However, it would require the addition of a second detent in the switching system, to enable the user to select if he/she were transmitting over the radio or speaking to the DVI system. While this is not an issue for the FP, the NFP currently uses a foot switch to activate the radios when flying. Adding a second detent on the existing foot switch was felt to be impractical and the addition of a second foot switch may result in confusion on the part of the NFP.

A keyword activation system would be "always on", but would not execute any commands unless the keyword had been spoken. The first model under consideration required each command to be prefaced with the keyword. While this model has merit in that inadvertent command execution is minimized and a degree of consistency is provided; that is, the keyword must be spoken before every command, exploring this concept during the role-playing exercise revealed that the repetition of the keyword quickly became frustrating to the user. An alternative model was then proposed, with the keyword being spoken before the initial command, followed by a time interval where the system remained active. After the time interval had elapsed, the system would "go to sleep" and require the user to speak the keyword in order to re-activate it. If the user did not want to wait for the system to "go to sleep", a keyword for de-activation was proposed. This alternative keyword activation model was employed during the OI evaluations.

2.4 FEEDBACK DEVELOPMENT

The content for the DVI feedback resulted from the syntax development through role-playing exercises. While the content had been determined by the end of the syntax development, no consideration was given to the format of the feedback. The first step in the syntax development was to generate a list of alternative formats. The following feedback methods were identified:

- a. synthesized speech;
- b. alerting tones;
- c. text/graphical display;
- d. indicator lights;
- e. synthesized speech and alerting tones;
- f. text/graphical display with indicator lights; and
- g. synthesized speech and text/graphical display.

Several advantages to auditory feedback were identified, the main advantage being that the input and output modality would be common. However, with the already high auditory workload in the Griffon, it was feared that another auditory system would increase the workload beyond human limits. Visual displays, while allowing persistence of information and not adding to the auditory load in the cockpit, would detract from the anticipated benefit of increased head-up time. Adding a visual feedback display would require pilots to bring their attention back inside the cockpit.

The interaction of an operator with the DVI system was modelled by plotting the Visual, Auditory, Cognitive and Psychomotor (VACP) ratings at one-second intervals, looking

for potential conflicts and high workload segments. The VACP Ratings were developed from a standard set of Attentional Demand Ratings used by BSC, developed by Aldrich [Reference 2]. The modelling of three feedback methods is presented in Figure 2-4, Figure 2-5 and Figure 2-6. The text in red represents DVI system responses, while text in black represents user commands. This technique also allowed an assessment of the timeliness of each feedback method. It should be noted that at the time the modelling was undertaken, the anticipated implementation provided two-stage feedback. After a command was recognized, simple feedback indicating that the system had recognized a valid command would be provided to the user. This would be followed by more detailed feedback, i.e. the content of the command, after the command was executed. This technique also allowed an assessment of the timeliness of each feedback method.

Given the high auditory and visual workload in the Griffon, the feedback method selected was a compromise between the auditory and visual channels. An alerting tone was provided to indicate success or failure. The alerting tone was accompanied by a small, text-based display used to present more detailed information and provide persistence.

2.5 CRM MODIFICATIONS

Because DVI allows hands-free interaction with aircraft systems, the possibility of assigning additional tasks to the FP was investigated. The current CRM model in the Griffon divides the cockpit duties in a straightforward manner: the FP flies the aircraft, maintaining HOCAC and the NFP performs the remaining cockpit tasks, e.g. configuring radios, managing the flight plan, monitoring aircraft systems, navigating. If the FP wishes to perform a cockpit task, e.g. change a radio frequency, he or she must ask the NFP to perform the necessary CDU operations.

Two benefits were anticipated by modifying the CRM so that the FP performs cockpit tasks in addition to flying the aircraft. The first benefit is an anticipated reduction in the NFP's workload, which often exceeds human performance limits. The second benefit is that the increase in cockpit communication will be minimized. If DVI were implemented using the current CRM, the FP would ask the NFP to perform a task, then the NFP would have to repeat the command verbally to make use of DVI. This would significantly increase the ICS traffic in an already busy cockpit.

The revised CRM model re-allocates two tasks to the FP. In addition to flying the aircraft (maintaining HOCAC), the FP is responsible for maintaining communications with the squadron and waypoint selection, e.g. incrementing/decrementing waypoints, initiating Present POSition (PPOS) direct. The NFP continues to perform the remainder of cockpit tasks.

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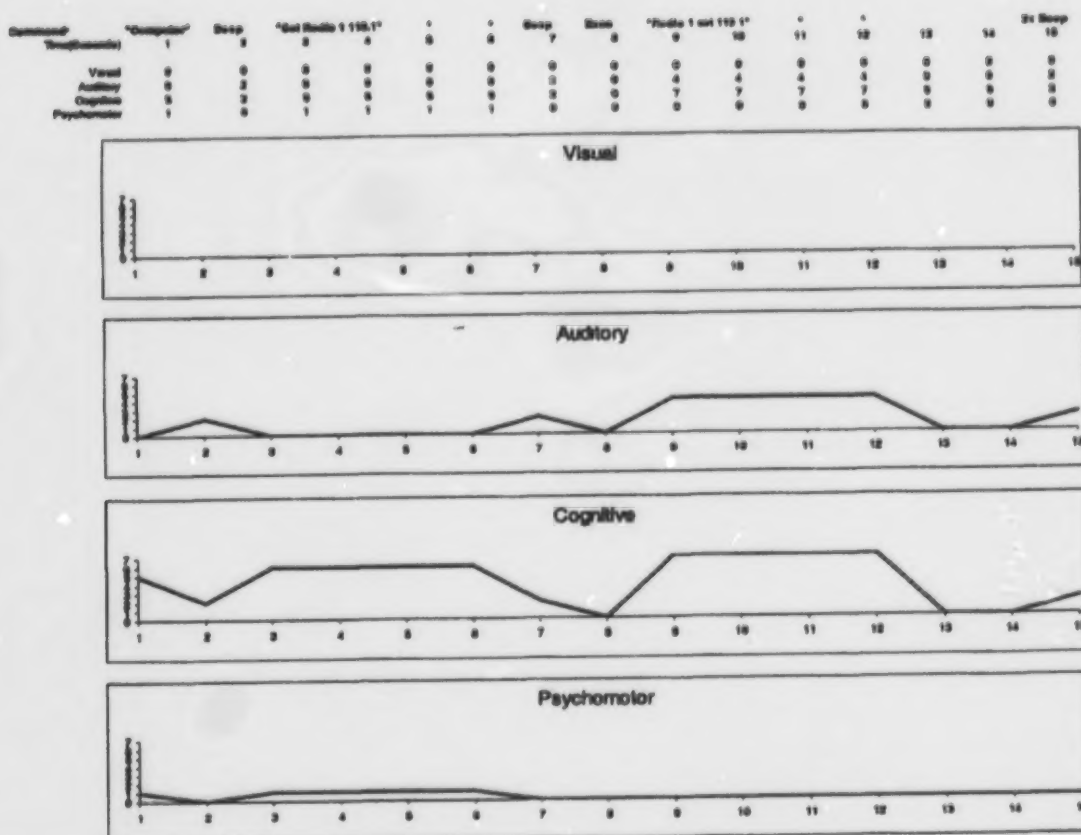


Figure 2-4 VACP Plots for Auditory Feedback (Tones + Speech)

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HUMAN FACTORS ENGINEERING

DOC NO
1000-1209

Command	"Computer Flash"		"Set Radio 1 115.1"		"		Processing Radio 1 call 115.1"		"		Flash		
Time(Seconds)	1	2	3	4	5	6	7	8	9	10	11	12	13
Visual	0	1	0	0	0	0	3	5	5	5	0	0	1
Auditory	0	0	0	0	0	0	0	0	0	0	0	0	0
Cognitive	5	1	5	5	5	5	2	7	7	7	0	0	1
Psychomotor	1	1	1	1	1	1	1	1	1	1	0	0	1

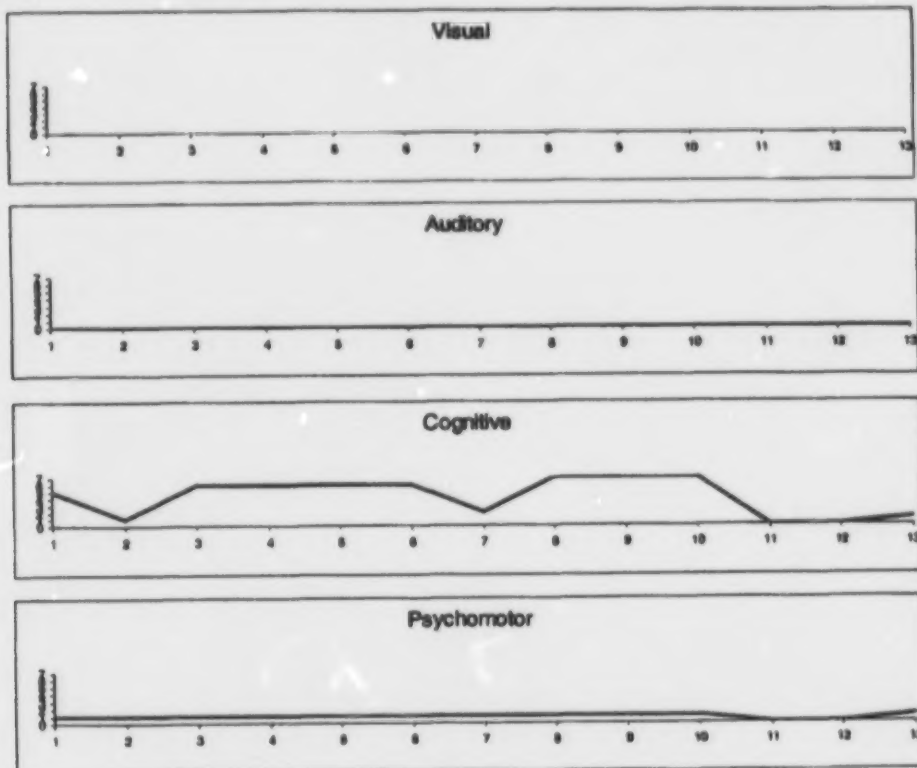


Figure 2-5 VACP Plots for Visual Feedback (Flashing Light + Text)

BAE SYSTEMS CANADA INC
HUMAN FACTORS ENGINEERING

DOC NO
1000-1209

Command	"Computer Sleep"		"Set Radio 1 119.1"		"		H Sleep and Processing (radio only)"		Radio 1 set 119.1"		"		2x Sleep"	
Time(Seconds)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Visual	0	0	0	0	0	0	0	0	5	5	5	0	0	0
Auditory	0	2	0	0	0	0	2	0	0	0	0	0	0	2
Cognitive	5	2	5	5	5	5	2	0	7	7	7	0	0	2
Psychomotor	1	0	1	1	1	1	1	0	1	1	1	0	0	0

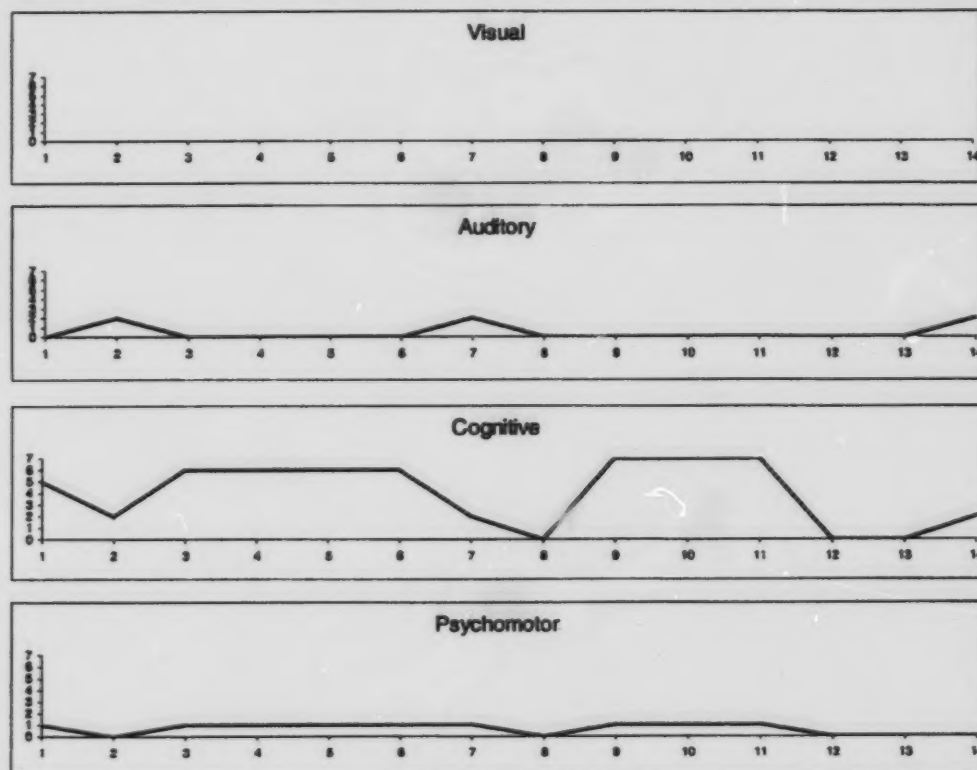


Figure 2-6 VACP Plots for Audio and Visual Feedback (Tone + Text Display)

SECTION THREE - OPERATOR INTERFACE EVALUATION¹

3.1 GENERAL

The purpose of the research presented herein was to assess a prototype DVI system which was developed as a possible control interface for the CH146 Griffon helicopter (see Section 2). Of importance is that the DVI system has the potential to reduce head-down time, especially for the NFP, by allowing commands to be entered without looking down at the CDU. Reduced head-down time should enhance flight safety and improve mission effectiveness by allowing the Griffon crew to spend more time looking out at the external scene.

The present assessment compared the prototype DVI system against the current MI CH146 Griffon cockpit configuration. Two experiments were conducted. In each experiment, six two-member crews, each consisting of an FP and an NFP, were required to fly a simulated Griffon through a series of representative missions. On each mission, the helicopter was equipped either with DVI capabilities or without DVI capabilities (MI condition).

In the first experiment, subjective evaluations of the DVI and MI systems were obtained from the FP and NFP. In addition, an objective measure of crew behaviour was obtained by using head-tracking apparatus to record the head positions of the FP and the NFP throughout the missions.

The second experiment assessed the attentional demands placed on the FP and NFP in the DVI versus the MI configuration.

3.2 EXPERIMENT 1: ASSESSMENT OF DVI IMPACT ON FLIGHT SAFETY

3.2.1 Purpose

The first experiment was designed to determine whether the prototype DVI system for the CH146 Griffon enhances flight safety and mission effectiveness. This was achieved by comparing the DVI system against the MI system that is currently used in the Griffon. Experienced and active CF Griffon crews, consisting of an FP and an NFP, flew a simulated Griffon through several route reconnaissance (recce) missions. The crew's task was to determine the extent of damage incurred from night-time raids. Each mission consisted of preparation of a flight plan (crew were provided with maps), start-up, take-off and landing procedures, setting and use of waypoints, search for contacts and submission of contact reports (using the SALUTE format) to an external agency, re-tasking, calculation of endurance and range, and frequent radio changes. Two experimenters acted as controlling agencies: ZERO and MAGIC. The experimenter with the call sign "ZERO" filled the role of the squadron command. The crew was instructed to engage in communications normally done in the real aircraft on similar missions, and therefore to request take-off and landing clearance and provide status reports to ZERO. The experimenter with the call sign "MAGIC" filled the role of the AirBorne

¹ Section Three was prepared as a standalone document by Dr. C. Herdman and other members of the Centre for Applied Cognitive Research at Carleton University.

Command and Control Centre (ABCCC), and was responsible for the current mission. The crew was instructed to provide MAGIC with status reports, and SITUATION REPOrts (SITREPs).

On each mission, the helicopter was equipped with either DVI capabilities or without DVI capabilities (MI condition). The Griffon is equipped with two central CDUs located between the seats and on the floor of the cockpit. Manual input into the CDU requires the user to look down into the cockpit. In contrast, the prototype DVI system includes two feedback displays that are situated on the front console and in the upward Field-Of-View (FOV) of the NFP and the FP. When a command is entered via the DVI system, the user can obtain feedback by looking at the DVI feedback display: the DVI user does not need to look down at the CDU to verify a command. While the CDU is not necessary to confirm DVI commands, it was available to the crewmembers during the DVI trial. If users wished to verify DVI commands directly on the CDU they were able to do so; however, they were required to navigate through the CDU menu structure, either manually or using DVI, to the appropriate page to verify the command, i.e. the page displayed on the CDU did not automatically change with the DVI command.

In the present experiment, the impact of DVI versus MI on the Griffon crew's behaviour was indexed using subjective and objective measures. Subjective measures of the DVI and MI systems were obtained from both the FP and the NFP via a battery of questionnaires. The objective measure of crew behaviour was obtained by measuring the amount of time that the crewmembers spend looking inside the cockpit and down at the CDU. This is referred to as "head-down time". *Reducing head-down time is assumed to enhance flight safety and mission effectiveness.* It was hypothesized that the DVI system would reduce the crew's head-down time because the DVI capability diminishes the need to manually input commands into the CDU and the positioning of the DVI feedback display allows the user to maintain a head-up position while executing and verifying commands.

In the current CRM for the CH146 Griffon, once the aircraft is airborne only the NFP enters commands (manually) into the CDU while the FP is required to maintain HOCAC. Accordingly, the addition of a DVI capability into the cockpit was expected to have the greatest impact on the head-down time of the NFP. The head-down time of the FP was expected to be minimal and undifferentiated across DVI versus MI conditions.

The integration of the DVI system into the cockpit involved modifying the current Griffon CRM to allow the FP to enter a limited number of commands into the CDU via voice. A priori comments from SMEs indicated that this CRM modification should reduce the workload on the NFP without noticeably affecting the FP's workload. It is possible, however, that allowing the FP to enter commands essentially "engages" the FP with the DVI system, not only through the issuing of commands but through visual and cognitive monitoring of the DVI feedback as well. This engagement may increase the workload on the FP relative to the standard MI system. Accordingly, in the present experiment, subjective measures of both NFP and FP workload were obtained.

3.2.2 Method

3.2.2.1 Participants

Twelve CF helicopter pilots, eleven males and one female, comprising six crews, volunteered for this study. All were considered on active duty. Two pilots were recruited from each of Squadrons 438 and 430, and four were recruited from each of Squadrons 400 and 427. Their demographics are shown in Table 3-1.

Table 3-1 Demographics of Participants in Experiment 1

Participant	Range	Average
Age	25 - 52	34.39
Years in CF	8 - 28	13.9
Total Flight Hours	696 - 6700	2422.2
Total Griffon Hours	120 - 1100	525.8

Several participants had previously used speech recognition systems. Three individuals participated in the voice recognition trials at the NRC (Swaile and Kobierski, 1997 [Reference 3]) and four participated in the DVI trials at DCIEM (Farrell *et al*, 1999 [Reference 4]).

3.2.2.2 Facility and Materials

The study was conducted using an ACD facility at the BSC Human Factors Engineering (HFE) Laboratory in Kanata. The ACD was driven by Silicon Graphics International (SGI) workstations (2 SGI Octanes, 2 SGI Solid Impact, and 1 SGI ONYX2) over a local area network. The distribution and configuration of software are presented in Figure 3-1. The simulator physical layout includes a flight deck structure with cockpit housing, seating for the flying pilot (always on the right), non-flying pilot (always on the left), and experimental observer (back left), as well as low fidelity flight control systems (cyclic, collective, rudder pedals).

The simulated environment was displayed on a rear projection screen (60 degree FOV) positioned approximately 8' 7" from the viewer. Monitors displayed the simulated left, right and centre instrument panels, the two CDUs, and the Communications System Console (CSC). The pilots interfaced with the CDUs using touch-activated bezels formatted to look and interact as the CDUs for the CH146 Griffon Helicopter. The CDUs were enabled to receive and act upon command messages from both manual input and from the DVI system. For each DVI command message received, the CDU responded with a status message indicating success or failure. To allow communication between the crew and controlling agencies, headsets and microphones were worn which allowed all interactions (except when in private mode) to be heard by both pilots and the controlling agencies. Participants had control of their headset volume. The participants' headsets were equipped with head trackers in order to measure head position throughout the trials. Ambient aircraft noise was presented over two small speakers (< 60 dBA) positioned at the rear of the ACD. Auditory feedback (tones), radio traffic and InterCommunications System (ICS) chatter was presented over the Verbex headsets. The cockpit configuration is illustrated in Figure 3-2.

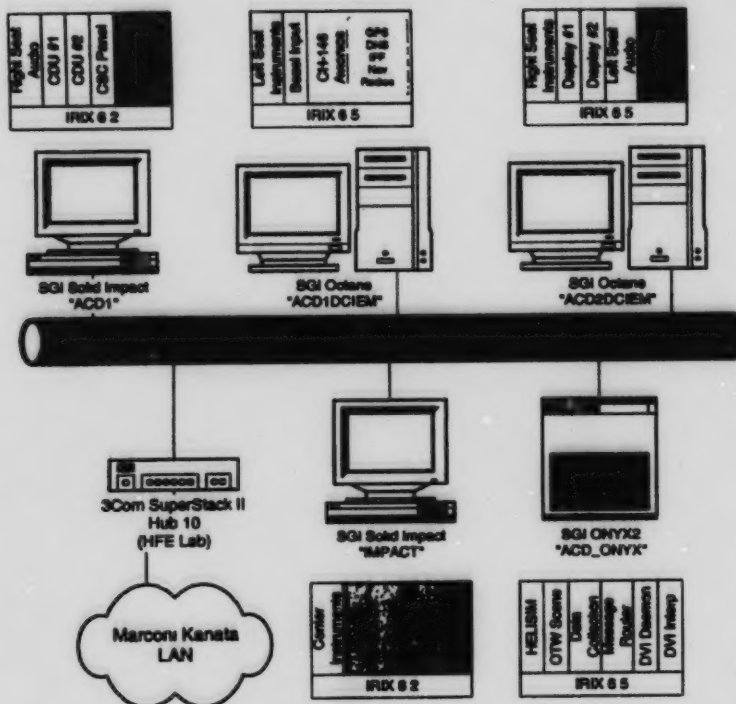


Figure 3-1 Software Distribution for the Aircraft Crewstation Demonstrator

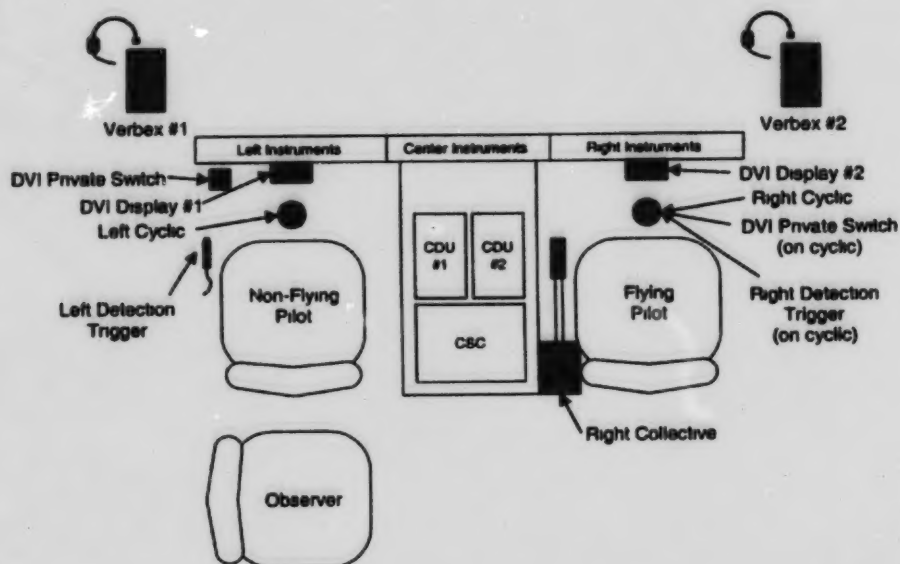


Figure 3-2 Aircraft Crewstation Demonstrator Cockpit Configuration for DVI Trials

3.2.2.3 Tracking Head Position and Flight Model

Head positioning of the FP and NFP was tracked throughout each mission using head trackers that were attached to the headsets. The two trackers were individually calibrated before the start of each trial by having the pilots look directly forward and then down at the CDU. A conservative definition of head-down versus head-up was adopted as the "X" and "Y" midpoints between looking directly forward versus looking to the side and down at the CDU.

The flight dynamics of the ACD were modelled using HELISIM, a high fidelity, six-degree of freedom simulation environment. The flight model utilized in the experiment was based on performance data for a Bell 412 helicopter. In addition, the flight model of the ACD was subjectively tuned to ensure a more realistic approximation of the handling characteristics of the Bell 412. A Stability Augmentation System (SAS) algorithm was active in the flight dynamics model.

3.2.2.4 DVI Syntax, Software, Functional Flow and Feedback System

The syntax for the prototype DVI system is detailed in Annex E. The software distribution for the prototype is presented in Figure 3-1. The functional flow of the prototype, illustrating the path followed by a DVI command, is presented in Figure 3-3.

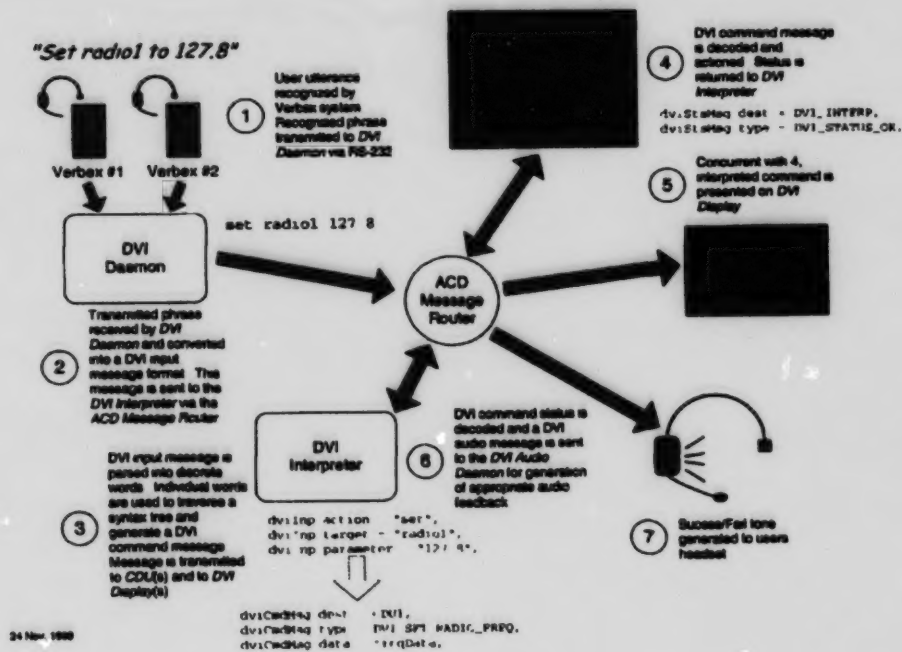


Figure 3-3 DVI Information Flow

Feedback from the DVI system was both auditory and visual in nature. The visual feedback was presented to both the FP and the NFP on two, 4-line by 25-character Liquid Crystal Displays (LCDs). The LCDs were positioned approximately 70 cm (10° visual angle) directly in front of each participant on the glare shield of the ACD. In addition, two small green lights were present on the feedback display. The first light indicated whether the system was in listening (lit) or in standby mode (not lit), and the second light flashed when the system was prompting for information, such as during a calculation.

3.2.2.5 Communication System Console

The traditional CH146 Griffon CSC has mechanically driven rotary dials and therefore it could not be interfaced through software with DVI. As a result, members of the HFE laboratory at BSC developed a new DVI-friendly CSC panel using a touchscreen overlaid on an LCD display.

Other DVI-specific components in the cockpit included a private mode switch for each pilot (a foot pedal for the NFP and a button on the collective for the FP). When pushed, the private mode prevented the other pilot and agencies from hearing the DVI communication. Two portable Verbex speech recognizers were positioned behind the instrument panel. The left detection trigger and the right detection trigger shown in Figure 3-2 were used to collect responses from the NFP and FP in the second experiment.

3.2.2.6 Questionnaires

Subjective assessments were obtained using a battery of questionnaires. As shown in Annexes F and G, there were separate questionnaires for the MI and DVI systems which included ratings and open-ended questions concerning the use of each system, the nature of the feedback, assessments of each CRM model, and the workload associated with each system. The workload segments in the questionnaires were developed from work performed during the DCIEM DVI experiment (described in Reference 4). Participants filled out these questionnaires separately and both as the acting FP and the acting NFP. A final questionnaire (Annex H) was used to collect subjective views concerning the effectiveness of the MI and DVI systems for completing the tasks required in the present study and for rating which system is preferred for completing these tasks. The final questionnaire also probed the participants' views concerning the criteria for inclusion/exclusion of commands into the DVI command set, nature of the DVI feedback, as well as the impact of DVI on situational awareness, flight safety and mission effectiveness.

3.2.3 Procedure

3.2.3.1 Controlling Agencies

Two experimenters (Carleton University Graduate students) were trained to act as controlling agencies: MAGIC and ZERO. Two additional people were trained as back-ups (the experimenter and a member of the BSC HFE Team). Training of personnel lasted approximately

4 hours, and included memorizing common aviation words and phrases, the phonetic alphabet, usual flight protocols, and some role-playing.

The individual with the call sign "ZERO" played the role of the squadron command. The crew was therefore instructed to engage in communications done normally in the real aircraft on similar missions, and therefore to request take-off and landing clearance and provide status reports to ZERO. The individual playing ZERO was also responsible for recording the timing of events (take-off, contact visual, etc.). The individual with the call sign "MAGIC" played the role of the ABCCC, and was responsible for the current mission. The crew was therefore instructed to provide MAGIC with status reports, and SITREPS. The scripts for MAGIC and ZERO are given in Annex I and Annex J, respectively.

The two controlling agencies were seated behind the cockpit and monitored the mission's progress via separate display screens. An experimental observer was situated at the back of the cockpit. The observer made notes and facilitated the crew occasionally if any problems arose, such as providing direction if the crew became lost, or pointing out any substantial deviation from the desired altitude or speed.

3.2.3.2 Overview

Each experiment was conducted over a period of two days (see Table 3-2 for schedule). A few days prior to the experimental sessions the pilots received an information package that described some aspects of the study, including a schedule of events, a list of the DVI syntax, as well as a brief description of the DVI interface.

Table 3-2 Schedule of Procedure for Experiment 1

Time	Day One	Time	Day Two
0800	Arrive, sign-in Introductions	0800	Arrive, sign-in
0820	Introduction to ACD Familiarity Flights	0815	New CRM review Retrain Verbex
1115	Break	1115	Break
1130	Manual Trial #1	1130	DVI Trial #1
1215	Questionnaire	1215	Questionnaire
1230	Lunch	1245	Lunch
1300	Manual Trial #2	1330	DVI Trial #2
1345	Questionnaire	1415	Questionnaire
1400	Manual Detection Trial	1445	Break
1430	Introduction to DVI	1500	DVI Detection Trial
1455	Break	1530	Final Questionnaire and Debrief
1505	Train Verbex System	1615	End of Day
1530	Introduce new CRM Familiarization with DVI and CRM in ACD		
1700	End of Day		

3.2.3.2.1 Day One

The pilots' background information and informed consent (see Annex K) were collected at the beginning of the first day. This was followed by an overview of the ACD, a familiarization flight to become familiar with the ACD's flight dynamics, a briefing regarding the purpose of the study, and a detailed description of the format of the missions. A practice flight facilitated by the domain expert was then performed for the purpose of ensuring all flight requirements and communications with the controlling agencies were being executed, and that the crew was comfortable with the mission. Two experimental trials (missions) were conducted using the MI (standard Griffon) configuration. Each mission lasted approximately 20 minutes. Questionnaires were administered immediately following each mission. The trials for the MI condition of Experiment 2 of this project were run after the Experiment 1 MI missions (plus questionnaires) had been completed.

Toward the end of Day One, a brief introduction to DVI was given, including an explanation of the syntax development process/rationale and an explanation of the feedback system. This was followed by voice training of the Verbex System which lasted approximately 30-45 minutes per participant. The Verbex System training involved having the participant sit at a computer console and read aloud all of the words and phrases used in the DVI prototype. After training the Verbex System, a description of the DVI CRM was reviewed and followed by practice using the DVI system while seated in the cockpit (i.e., not flying).

3.2.3.2.2 Day Two

Day Two started with a review of the DVI CRM used for the experimental trials. This was followed by a second training session of the Verbex System in order to ensure good recognition accuracy. A practice mission was flown facilitated by the domain expert to ensure that the crew was comfortable with the DVI syntax and with using the DVI System.

Two DVI experimental trials were flown during Day Two, followed by the DVI trial for Experiment 2. At the end of the day the final questionnaire (Annex H) and a debriefing (see Annex K) were given. The debriefing included an explanation of the objective measures and the expected results, and well as an opportunity for the crew to make further comments regarding the study.

3.2.3.2.3 Crew Arrangement and Mission Scenarios

During the first trial, for both the MI and the DVI conditions, the crewmembers were seated in their typical configuration, that is with the most senior crewmember acting as the NFP and the more junior member as the FP. This was followed by a role reversal for the second trial. The first seating configuration was retained for Experiment 2.

Four different experimental missions were flown, partially counterbalanced across DVI and MI conditions, with a separate (fifth) mission being used for all practice sessions. The same order of components was included for all missions; however, different routes (waypoints and features) were included. Each crew was given a maximum of 10 minutes before each trial (mission) to prepare their flight plan. They were provided with a new map, new flight plan data,

and a copy of the mission scenario at the start of each trial. The maps used the Military Grid Reference System (MGRS) as seen in Annex L, in which grids are labelled with numbers along each axis. Once comfortably seated in the cockpit, an audio check was executed, and the head tracker was calibrated by requesting the pilots to look out, then look at the CDU. Once completed, the crew was given a maximum of two minutes to input its flight plan and communication information, and prepare for take-off. The tasking information listed in the following subparagraphs was given to the crew for each mission:

- | | | |
|----|---|---|
| a. | Unit: | 403 |
| b. | Mission Number: | AS165R |
| c. | No. Helos: | 1 |
| d. | Nature of Task: | Route Recce/Standby for CSAR |
| e. | Estimated Duration: | 0.5 h |
| f. | Call Sign and Frequency: | Squadron C/S: "ZERO" - 119.1 |
| g. | Airborne Command Control and Communication: | Call Sign "MAGIC" - 120.7 |
| h. | Combat Intelligence Update: | MAGIC is coordinating agency. There has been significant night-time activity with little activity during the day. Focus of recce missions is to determine the extent of damage during these night-time raids. |
| i. | Remarks: | Fast air hard deck at 300' Above Ground Level (AGL), all helicopters to remain 200' AGL and below. Rotary wing airspeed restriction of 60 KIAS for coordination control. Mandatory reporting crossing phase lines to all coordinating agencies. |

Crews started each mission at the same location (HOME). They were then required to fly to the first waypoint indicated on their flight plan, which was the beginning of the first leg of their recce mission. Their goal was to follow the feature indicated on their flight plan to their next waypoint (the end of the RECCE), look for any possible contacts (described as some form of burning vehicle or debris), and to file a contact report (SITREP) with MAGIC. Pilots were instructed to use the SALUTE format for their contact reports, which consisted of naming the Size, Activity, Location, Unit, Time, and any other pertinent information. Toward the end of the first leg of their RECCE they received a communication from MAGIC stating that they had been re-tasked and therefore the second leg of the mission had changed. Once they received the re-tasking information, they were to complete the first leg and go directly to the next waypoint (the beginning of their second leg). The mission remained the same, to follow the main feature

(river, coastline, road, etc.) to the end of the leg, and then to proceed directly to HOME. On their way home, MAGIC informed them of a possible CSAR mission, and requested their endurance and range. Once the crew forwarded this information to MAGIC, they were informed that they were no longer required for that mission and should return to HOME. Pilots were instructed to let both ZERO and MAGIC know when they crossed the phase line (APPLE) and to forward their flight status. During each mission one contact was present on each leg of the RECCE, varying in type and position. Frequent radio changes were requested by MAGIC throughout the mission to ensure substantial interactions between the crew and the CDU and DVI interfaces.

3.2.4 Results

3.2.4.1 Subjective Ratings and Written Comments

3.2.4.1.1 Manual Input Condition

The CDU was implemented in the flight simulator to closely resemble the CDU that exists in the Griffon helicopter, in appearance and function. An eight-item questionnaire (see Annex F) was administered to obtain pilots' views concerning manual input into the CDU. Questions 1 to 5 involved ratings, whereas questions 6 to 8 were open-ended. A summary of the response to the rating questions is presented in Annex M, while Annex N summarizes the responses to the open-ended questions. A synopsis of the questionnaire responses is presented in the following sub-paragraphs.

- a. **Question 1.** NFPs looked at/attended to the CDU frequently/often (Q1a, 1b) and sometimes experienced visual conflicts (Q1c). In contrast, FPs rarely looked at/attended to the CDU and rarely experienced visual conflicts. Both the NFPs and FPs occasionally experienced auditory conflicts (Q1d).
- b. **Question 2.** On average, both the NFPs and FPs found the amount of feedback from the CDU to be appropriate, although 3 of the 12 of the FPs indicated that the CDU provided "far too little feedback".
- c. **Questions 3 and 4.** The feedback was judged by the NFPs as being "somewhat adequate" to complete tasks (Q3) and to troubleshoot the system (Q4), whereas on average the FPs responded "neutral" to these questions.
- d. **Question 5.** Of interest is that both the NFPs and the FPs found that the ease of dividing attention between the CDU and the outside visual scene was "borderline." It is worth noting that 5 of the 12 NFPs found dividing attention to be difficult.
- e. **Question 6.** Under the current CRM training, the FP makes only occasional glances to the CDU when the aircraft is airborne. When acting as the NFP, pilots noted that a lot of time is spent looking at the CDU to enter and confirm data. This takes time away from looking at the outside scene and at the map.
- f. **Question 7.** All 12 participants noted indicated that, with a few exceptions, the implementation of the CDU on the flight simulator was a good facsimile

of the CDU in the Griffon. One point noted by 8 of the 12 participants is that the time response to the simulator CDU was noticeably slower than the CDU response in the Griffon. Future implementations of the CDU on the simulator should attempt to eliminate this discrepancy.

- g. **Question 8.** Participants made a number of comments on the current Griffon CRM. Of particular note, is that 4 of the 12 pilots stated that in reality, "the FP can operate a radio when the workload of the NFP is excessive". Without DVI, this would require the FP to remove one hand from the flight controls.

3.2.4.1.2 DVI Condition

The questionnaire for the DVI system was similar to that used for the manual input configuration, but expanded in that questions were asked concerning the CRM that was modified for the DVI condition of the experiment (see Annex G). As for the MI trial, results are summarized in Annex M and Annex N and a synopsis of the results is presented in the following sub-paragraphs.

- a. **Question 1.** NFPs looked at/attended to the DVI feedback display frequently/often (Q1a / Q1c). In contrast to the manual condition where the CDU was viewed frequently/often, in the DVI condition NFPs only occasionally looked at/attended to the CDU (Q1b / Q1d). Visual and/or auditory conflicts were experienced only rarely (Q1e-f). FPs indicated that they looked at/attended to the DVI feedback display sometimes/frequently to often (Q1a and Q1c). This shows a distinct change from the FPs behaviour in the manual input mode: with DVI the FPs frequently "interacted" with the system, at least by monitoring the feedback. As in the manual mode, FPs rarely looked at the CDU (Q1b and d) and rarely experienced visual or auditory conflicts (Q1 e and f).
- b. **Question 2.** On average, both the NFPs and FPs found the amount of feedback provided by the DVI system to be "appropriate".
- c. **Questions 3 and 4.** The type of feedback was judged by the NFPs to range from very adequate to neutral (Q3). The DVI auditory feedback was rated as somewhat inadequate for troubleshooting (Q4d). The FPs rated the type of feedback as neutral to very adequate (Q3) and generally found the feedback to be favourable for troubleshooting (Q4).
- d. **Question 5.** Both the NFPs and the FPs found that in the DVI configuration it was "Easy" to divide attention between the DVI display and the outside visual scene. This contrasts to the manual system where dividing attention between the CDU and the outside scene was rated at "Borderline".
- e. **Question 7 and 8.** On average, participants agreed that the division of duties between the NFP and the FP was appropriate in the DVI CRM (Q7). Participants noted that NFP and FP duties were rarely mixed up or inappropriately taken over by the other crewmember.

- f. **Questions 6 and 9.** Participants noted that DVI would be a very useful tool as it allows both pilots to focus their attention outside the cockpit. A number of comments concerning DVI feedback (Q6) and the DVI CRM (Q9) are listed in Annex N. These comments should be taken into consideration in future developments of the DVI system.
- g. **Questions 10, 11 and 12.** Participants' comments/suggestions concerning the individual DVI vocabulary words (Q10), memory and use of DVI commands (Q11), and DVI recognition problems (Q12) are listed in Annex N. These comments provide insights into suitable adjustments to the DVI vocabulary and syntax that should be considered.

3.2.4.1.3 Final Questionnaire

The final questionnaire (see Annex H) was administered at the completion of the experiments on Day Two. A summary of the responses to the final questionnaire are given in Annexes M and N. The highlights of the responses are presented in the following subparagraphs.

- a. **Question 1.** A series of ratings was obtained in Q1 concerning the use of the MI and DVI systems for entering a representative sample of commands from the present experiment. Of primary interest is that the DVI system received higher ratings for several items. In particular, the DVI system was rated higher than the manual on both a cluster of communication items (Q1p, q, r, s) and activating present position.
- b. **Question 2.** Responses to Q2 are especially telling in that for all but 4 of the 19 functions, the DVI system was rated as being preferred over the MI system. There was no case where MI was preferred over DVI.
- c. **Questions 3 and 4.** Participants rated both "frequency of use" and "workload" as important criteria for inclusion of commands into the DVI set (Q3). "Task complexity" and "potential for audio conflicts" were rated as quite important as exclusion criteria.
- d. **Questions 5.** Participants provided a number of comments concerning other criteria for determining when DVI should be used. Of particular note is that DVI may be able to make some complex tasks easier.
- e. **Question 6.** Compared to manual input, participants rated DVI as providing a slight enhancement to spatial orientation, awareness of communications, flight safety and mission effectiveness. No change was detected for awareness of aircraft systems and, on average, a slight degradation in crew awareness was noted with DVI.
- f. **Question 7.** Compared to manual input, participants rated DVI as providing a slight to substantial enhancement of head-up time.

- g. **Question 8.** A number of suggestions for additional functionality of future DVI systems were suggested by the participants. These need to be fully considered.
- h. **Question 9.** All 12 participants indicated that the most usable DVI implementation would be a hybrid system.

3.2.4.1.4 Workload: Subjective Ratings

Participants provided subjective ratings of workload after completing each session, that is, after the MI session on Day One and after the DVI session on Day Two. The mental workload questionnaires are shown in Annex M for the MI and DVI conditions, respectively. Ratings were obtained from each participant as both the FPs and as the NFPs. Ratings were divided across three mission segments (transit and recce; re-tasking; contact, observation and report) and ten type of workload (visual, auditory, mental, physical, time, performance, effort, frustration, anxiety, global).

The ratings for the various conditions are summarized in Figure 3-4. The bars in Figure 3-4 represent difference scores. Difference scores were computed by subtracting the participant's rating assigned to the DVI item from their rating to the corresponding MI item. A positive value indicates that the workload was judged as less in the DVI than in the MI condition.

As shown in Figure 3-4, for the NFP role, participants rated workload as generally being less in the DVI than the MI condition. Individual t-tests showed that the for mission Segment #1 (transit and recce) advantage for DVI over MI was significant in the visual ($t(11) = 3.56, p < .005$), time ($t(11) = 2.20, p < .05$), anxiety ($t(11) = 2.16, p < .055$) and global ($t(11) = 2.66, p < .023$) indices. For Segment #2 (re-tasking) of the mission, a DVI workload advantage over MI was perceived in the visual ($t(11) = 2.80, p < .018$), physical ($t(11) = 2.60, p < .026$) and time ($t(11) = 1.75, p = .10$) indices. The only workload advantage of DVI over MI in Segment #3 (contact, observation, report) was noted in the visual index ($t(11) = 1.87, p = .089$).

For the FP role, participants rated workload as less in the DVI than the MI condition only in mission Segment #3 (contact, observation, and report) and only for the visual workload index ($t(11) = 4.10, p < .002$). Interestingly, for mission Segment #2, the workload on the FP was generally considered to be greater in the DVI than the MI condition. This subjective impression of increased workload on the FP on the DVI condition concurs with the results of Experiment 2 where objective measures of attentional demand were obtained.

In summary, participants perceived DVI as reducing workload relative to MI, but primarily only for the NFP. As expected, the reduction in workload for NFPs was not found across all indices: DVI was perceived primarily to reduce visual and time demands, although there were instances where anxiety, global and physical workloads were perceived to be reduced by DVI.

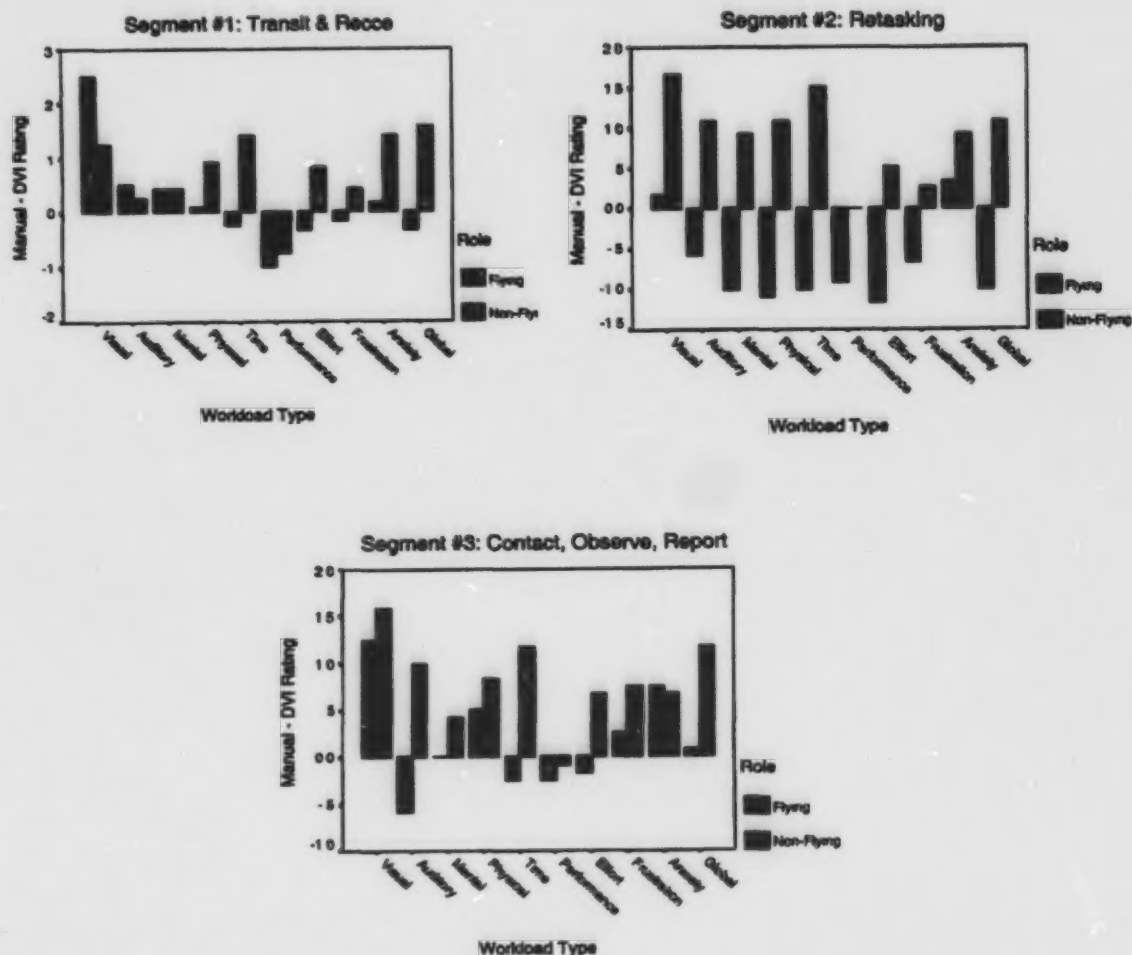


Figure 3-4 MI-Minus-DVI Workload Ratings For Each Mission Segment

3.2.4.2 Objective Measure of Performance: Head-Down Time

A goal of the present study was to determine whether DVI reduces the amount of time the Griffon crew spends looking down at the CDU. Because the FP is required to maintain HOCAC once the aircraft is airborne, the addition of a DVI capability was only expected to reduce the head-down time of the NFP relative to the manual condition. For the FP, DVI may reduce head-down time during initial start-up activities. Head position was measured throughout the complete mission. Separate measurements of FP and NFP head position were obtained.

As shown in Figure 3-5, across the complete mission, the percent head-down time for the NFP was reduced significantly and substantially in the DVI condition as compared to the MI condition. For the FP, head-down time was minimal and undifferentiated across DVI versus MI.

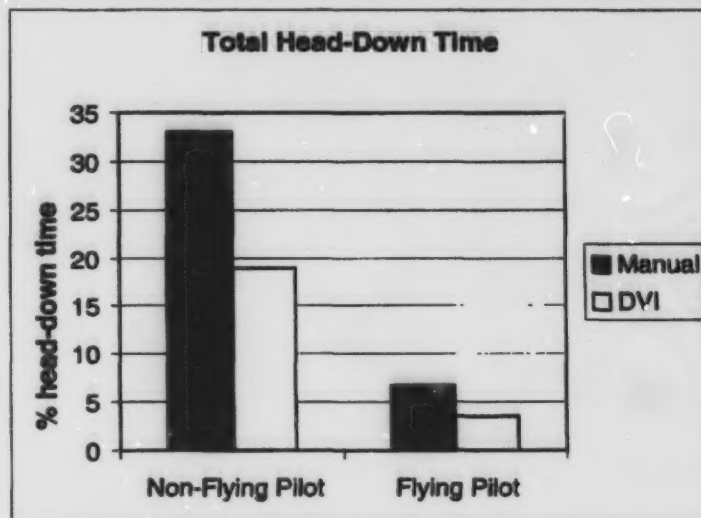


Figure 3-5 Total Percent Head-Down Time Computed Across All Mission Components

Figure 3-6 shows percent head-down time divided into the six mission events for the NFP (top panel) and the FP (bottom panel). The six events are described in Table 3-3.

Each crew entered a given event at different times. Accordingly, the beginning and end of events was marked in the data files and used to define the crew location in the given mission. The event cut-off times for each crew are shown in Annex O.

For the NFP, the percent head-down time was less in the DVI than the MI condition across all phases of the mission. For the FP, DVI only reduced percent head-down time during initial start-up to take-off.

In summary, the results are clear in showing that, compared to MI, DVI reduces significantly the proportion of time that the NFP spends looking down into the cockpit.

3.2.5 Summary of Experiment 1

The subjective and objective measures that were obtained in this experiment provide a cohesive and convincing conclusion. Compared to the MI configuration that is currently implemented in the CH146 Griffon, DVI provides an interface that should improve flight safety and mission performance by freeing the NFP from the requirement to look into the cockpit and down at the CDU to enter and verify commands.

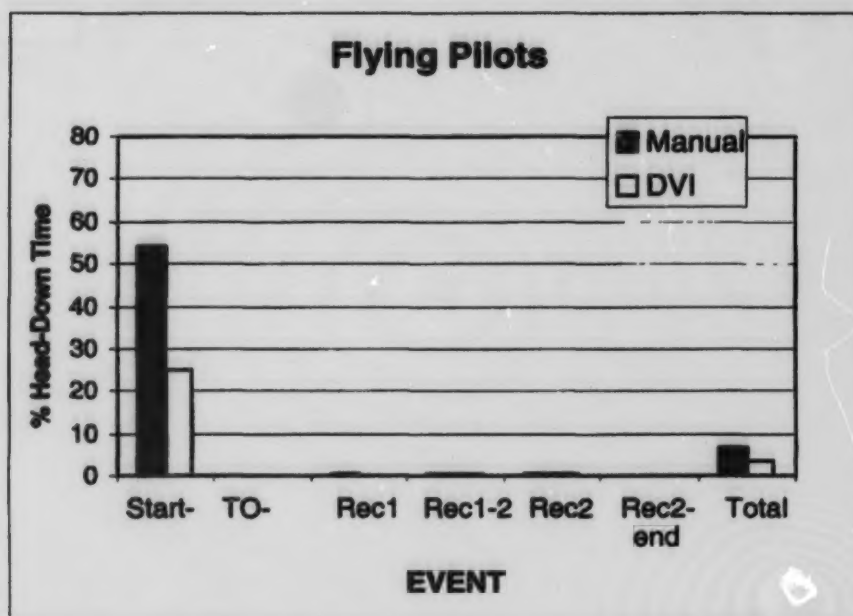
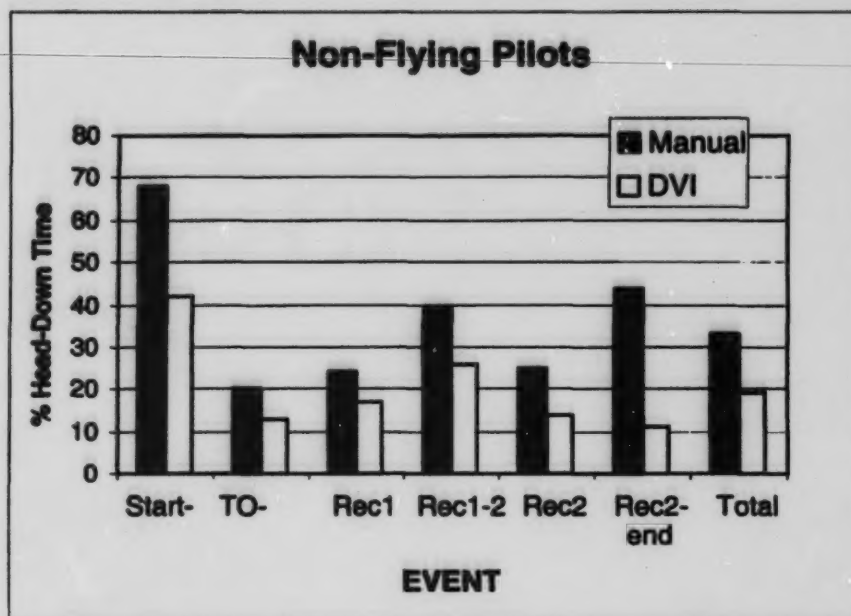


Figure 3-6 Percent Head-Down Time For Each Mission Component

Table 3-3 Mission Events

Event Number	Action
Event 1	Start-up to take-off
Event 2	Take-off to start of recce 1
Event 3	Start recce 1 to complete recce 1
Event 4	Complete recce 1 to start recce 2
Event 5	Start recce 2 to complete recce 2
Event 6	Complete recce 2 to landing

3.3 EXPERIMENT 2: MEASURE OF ATTENTIONAL DEMANDS

3.3.1 Purpose

The results of Experiment 1 show that implementing DVI in the CH146 Griffon helicopter can enhance flight safety and mission performance by reducing the amount of time that the NFP spends looking inside the cockpit. In addition, the pilots' subjective reports reflect an overall positive assessment of the DVI system and a preference for DVI over MI for many functions. Indeed, several pilots suggested that the DVI capability could be enhanced beyond the functions that were modelled and assessed in the current project.

It is important, however, that the impact of DVI on crew behaviour is considered fully. One issue of concern is the extent to which the FP becomes engaged with the DVI system not only directly through the execution of commands, but also indirectly through the monitoring of DVI feedback (for both crewmembers). In the current implementation, the FP interacted with the DVI system through a modified CRM in which the FP was allowed to enter a (limited) set of commands and via placement of the DVI feedback display in the upper visual field of the FP.

Participants reported that as FPs they could interact with the DVI system without compromising performance on other tasks. There were, however, two indicators in Experiment 1 which suggest that FP behaviour was changed significantly in the DVI versus the standard MI configuration. First, as indicated in responses to Q1a and Q1c of the DVI questionnaire, participants tended to look frequently at the DVI feedback display when acting both as the NFP (expected) and as the FP (not expected). This latter finding suggests a distinct change in FP behaviour compared to that in the MI configuration where the FPs reported rarely looking at the CDU display. Second, for mission Segment #2 (re-tasking), the FPs gave overall workload ratings that were "higher" in the DVI than in the MI condition ($t = -2.87$, $p < .05$; see Figure 3-4). Taken together, these two results suggest that FPs "engaged" the DVI system by issuing commands and monitoring the feedback, in both visual and cognitive domains. This engagement may increase the workload of the FP.

It is impossible for participants to introspect accurately on the efficiency and effectiveness of their behaviour in complex information processing tasks. Accordingly, the subjective reports of workload that were obtained in Experiment 1 are suggestive but must be interpreted with caution. The primary purpose of Experiment 2 was to obtain an objective measure of the attentional demands that are placed on the Griffon crew in the DVI versus the MI configuration. This was achieved by having the NFP and the FP perform a detection task in

which they responded to the presentation of visual and auditory targets while flying missions with the DVI versus the MI system.

The attentional demands of the FP will be reflected in responses to visual and auditory targets. The null hypothesis is that the presence of the DVI system does not affect the FP's distribution of visual attention nor their allocation of attentional resources. To support this hypothesis, the FPs' responses to visual and auditory targets should be undifferentiated across DVI versus MI conditions. There are two alternative hypotheses. First, in the DVI configuration, the FP may focus their "spotlight" of visual attention on the DVI feedback display, thereby limiting the efficiency to which information is processed beyond the display in the outside scene. Focusing attention on the feedback display at the expense of processing the external scene should result in performance costs for the FP in the visual detection task. Second, FPs may allocate a portion of their general attentional resources to the DVI system, thereby potentially reducing the amount of resources available for processing other tasks. This should be reflected in performance decrements on both the visual and the auditory detection tasks.

For NFPs, it was assumed that reduced head-down time would enhance flight safety and mission effectiveness by increasing the amount of time and attention that the NFP is able to allocate to the external scene. In the present experiment this should result in better performance on the visual detection task in the DVI as compared to the MI condition. There are, however, two possible reasons why a head-up position may not enhance the NFP's processing of the outside scene. First, as with the FPs, NFPs may focus their "spotlight" of visual attention on the DVI feedback display, thereby limiting their processing of targets in the outside scene. This would be reflected in performance costs in the visual detection task. Second, although looking "up and out", the NFP may need to allocate attentional resources to maximize their interactions with the DVI system, thereby limiting their ability to attend to and process information in the outside scene or from within the cockpit. This allocation strategy would be reflected in performance costs on both the visual and the auditory detection tasks.

3.3.2 Method: Participants, Facility and Procedure

The participants and testing facility were the same as described in Experiment 1. Targets for the visual and auditory detection tasks were presented for 500 msec at intervals of 8 +/- 4 s (randomly determined). Targets for the visual detection task were green orbs (full colour saturation) positioned in the centre of projection screen and subtending approximately 3 degrees of FOV. Targets for the auditory detection task were audio white noise ("buzz") presented over the NFP and FP headphones.

Each crew performed one session of the detection experiment on Day One and one session on Day Two. Each session started with a baseline condition during which the visual and auditory targets were presented over a 10 minute period while the pilots were in the ACD cockpit with the helicopter sitting on the ground. The FP responded to targets by pulling the trigger on the cyclic. The NFP responded by depressing a thumb switch on a small device held in the left hand. Participants were instructed to respond as quickly and as accurately as possible. Following the baseline session, the detection task was performed in combination with flying a recce mission similar to those flown in Experiment 1. Participants flew the mission while concurrently monitoring and responding to visual and auditory targets.

3.3.3 Results

3.3.3.1 Head-Down Time in Experiment 2

As in Experiment 1, the FP and NFP head positions were monitored throughout the missions. A summary of percent head-down time collapsed across the entire missions is shown in Figure 3-7. For NFPs the percent head-down time was significantly reduced in the DVI (11.3%) as compared to the MI (35.7%) condition. For the FPs, head-down time was minimal (average of 1.6%) and undifferentiated across DVI (0.9%) versus MI (2.3%) conditions.

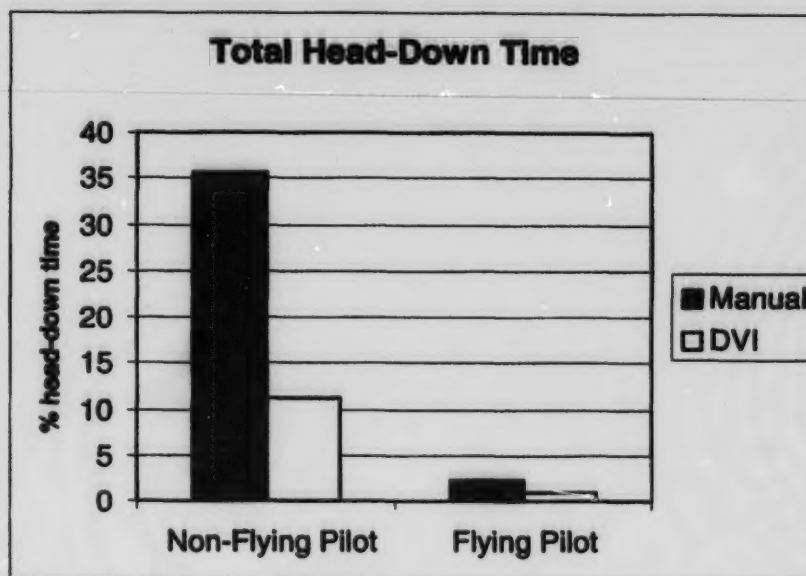


Figure 3-7 Total Percent Head-Down Time Computed Across All Mission Components

In summary, the head position data closely replicates Experiment 1 in showing that DVI substantially reduced head-down time for the NFP. The close similarity of the results across the two experiments shows that the introduction of the detection tasks in the present experiment did not categorically change the behaviour of the crew during the missions.

3.3.3.2 Visual and Auditory Detection Tasks

Median response latencies and misses for the FPs and the NFPs were computed for the baseline sessions and for each corresponding mission. Difference scores were calculated by subtracting each participant's baseline performance from the corresponding dual-task (detection plus mission) performance. A positive difference score indicates that performance was worse in the dual-task than in the baseline condition.

The latency and "miss" data were analyzed in separate 2 (Role: FP vs. NFP) x 2 (Detection: visual vs. auditory) x 2 (Configuration: DVI vs. MI) by 2 (Task: baseline vs. dual-

task) ANOVAs with repeated measures on all factors. Individual comparisons discussed in the text were based on the 95% confidence intervals which were computed using the error term from the 4-way interaction.

3.3.3.2.1 Non-Flying Pilots

Figure 3-8 shows the NFPs' baseline to dual-task performance changes for the visual and the auditory detection tasks in the DVI versus the MI condition. As expected, responses were both slower and less accurate (more misses) in the dual-task than in the baseline condition (shown as positive values in Figure 3-8). Overall decrements in performance from baseline to dual-task conditions are interpreted as reflecting specific attentional costs associated with the NFP performing other tasks concurrently with the detection tasks and/or concurrence costs associated having to time-share the tasks.

Of primary interest is that the baseline to dual-task decrements on the visual detection task were significantly less in the DVI than in the MI condition: differences of 70 ms in latency and 25% in accuracy. This result shows a clear consequence of reduced head-down time; the NFP is able to detect and respond more readily and accurately to visual target in the outside scene. This finding is also important in showing that the NFPs were not restricting their visual attention to the DVI feedback display. Decrements in performance on the auditory detection tasks were undifferentiated across DVI versus MI conditions, thereby showing that the NFPs' allocation of general attentional resources did not differ between the two interfaces.

In summary, the detection results show that the impact of DVI on reducing the NFP's head-down time comes with an accompanying benefit: faster and more accurate target detection in the outside scene.

3.3.3.2.2 Flying Pilots

Figure 3-9 shows the FPs' baseline to dual-task performance changes for the visual and the auditory detection tasks in the DVI versus the MI condition. As expected, responses were both slower and less accurate (more misses) in the dual-task than in the baseline condition (shown as positive values in Figure 3-9). As noted above, overall decrements in performance from baseline to dual-task conditions reflect specific attentional costs associated with performing other tasks concurrently with the detection tasks and/or concurrence costs associated having to time-share the tasks.

The baseline to dual-task decrements on the visual and auditory detection task yielded surprising and potentially critical results that could impact on the development of a fielded DVI system.

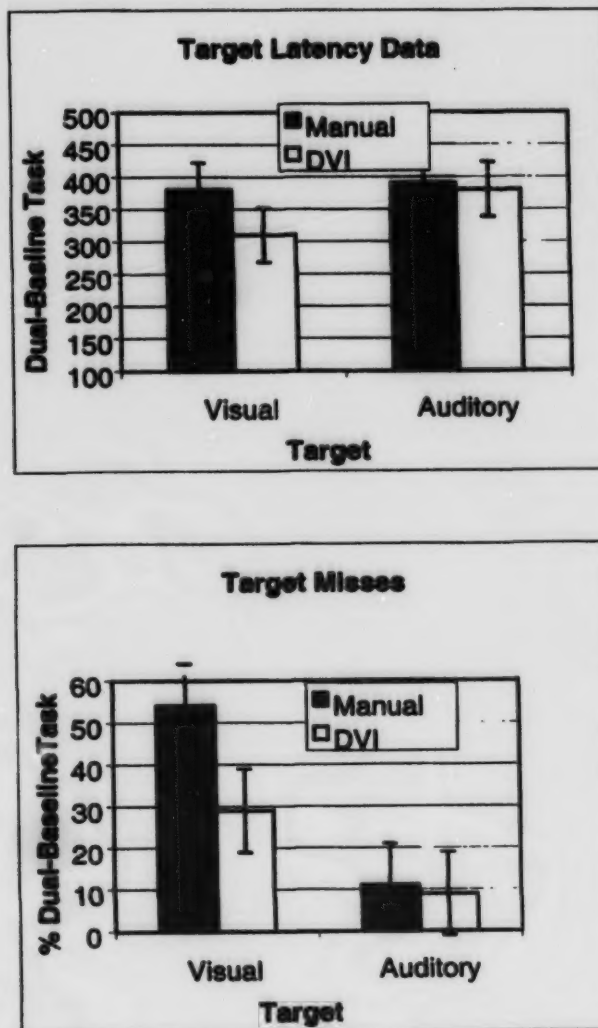


Figure 3-8 Non-Flying Pilot Detection Task: Dual-Baseline Scores
(bars with 95% confidence intervals)

As shown in Figure 3-9, decrements in performance on the visual detection task were significantly (71 msec) greater in the DVI condition than in the MI condition (changes in misses did not differ). That is, the implementation of the DVI system had a negative impact on the FPs: relative to the MI condition, the FPs were less able to quickly detect and respond to visual targets in the external scene.

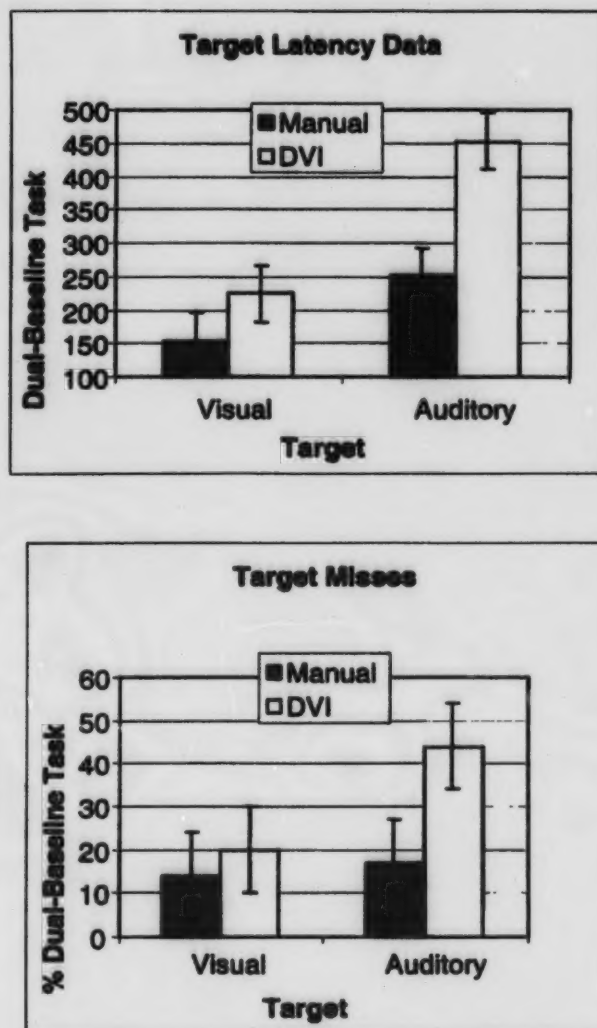


Figure 3-9 Flying Pilot Detection Task: Dual-Baseline Scores
(bars with 95% confidence intervals)

The auditory detection data show an equally critical outcome of DVI. For the FPs, baseline to dual-task performance decrements were significantly greater in the DVI than in the MI condition: decrements on auditory detection were greater by 202 msec in the latency data and 27% in the error data for the DVI versus the MI condition. This shows that the FPs allocated a substantial proportion of their attentional resources to the DVI system.

3.3.4 Summary of Experiment 2

The results of Experiment 2 have two major implications. First, the results show that for the NFPs, DVI not only reduces head-down time but also improves the NFPs' ability to detect and respond to visual targets. This should improve flight safety and mission performance of the CH146 Griffon crew. The DVI system does not appear to place noticeable demands on the NFPs' overall allocation of attention nor does it over tax the NFPs' resources for processing auditory information.

Second, the DVI system can have a negative impact on the FP's allocation of attentional resources and presumably on the FPs' ability to perform their primary tasks. Compared to the MI condition, FPs' were slower to respond to both visual and auditory targets in the DVI condition and they missed significantly more auditory targets. These findings show that a DVI system in the Griffon cockpit can have negative consequences on the FPs' performance.

3.4 CONCLUSIONS

3.4.1 Overall Evaluation of the CH146 Griffon Prototype DVI System

The present assessment has shown that the proposed DVI system can have a positive and significant impact on the performance of CH146 Griffon crew. The CF pilots who participated in this study evaluated the DVI system favourably. Pilots indicated that the DVI system reduced the workload of the NFP and reduced the amount of time that the NFP was required to look down into the cockpit. Objective measures of behaviour confirmed these subjective reports. In particular, relative to the current MI configuration, DVI was shown to substantially reduce the NFP head-down time. This resulted in faster and more accurate detection of visual targets in the external scene for the NFP.

It is concluded that a DVI system has the potential to enhance flight safety and mission performance for crew in the CH146 Griffon.

3.4.2 Toward a Fielded System: Further Developments

3.4.2.1 Attentional Demands on the Flying Pilot

The results of the present evaluation showed that the FPs allocated attention toward the DVI system. This allocation may have occurred because the FPs had the capability to manipulate cockpit systems with DVI through commands and/or because the FP was able to interact with the information provided by the DVI system, i.e. feedback. Allocation of attention toward the DVI system may have a negative impact on the FPs performance on other tasks.

The impact of FPs allocating attention toward the DVI system is a primary issue that could have an impact on flight safety and the performance of the Griffon crew. This issue needs to be understood and resolved. Further research should be conducted to understand the interaction between the FP and the DVI system in the modified CRM that was implemented in the present study. Alternatives should be tested, in particular, integrating DVI into the current Griffon CRM and thereby eliminating the FP's ability to interact with the DVI system (including

the DVI feedback). As in the present research, both subjective and objective measures of behaviour need to be collected in any future research.

3.4.2.2 DVI Command Set

The pilots in this study were able to remember and use the set of DVI commands effectively. It is possible that the command set could be extended. In addition, pilots indicated that alternative commands and alternative paths within the set could be added.

3.4.2.3 DVI Feedback

Pilots provided ratings and comments concerning the DVI feedback. Generally, the combination of auditory tones and visual feedback of the commands was judged to be effective. It is not clear, however, whether auditory feedback should be extended to include not only tones, but also voice (e.g., computer generated repetition of the input). An advantage of using voice feedback is that the user could enter a command and receive feedback while looking away from the DVI feedback display. It is possible, however, that voice feedback would create unwanted auditory traffic in the cockpit and would be harder for the user to verify.

3.4.2.4 Integrating DVI with other Advanced Cockpit Systems

Several pilots noted that a DVI system would be especially useful when NVGs are used in the Griffon. A clear advantage is that DVI would reduce the requirement for the pilot to look under the NVGs in order to enter and obtain information on the CDU. Another potential application would be to modify the command set so that the DVI system could be used to change pages and symbology on the (forthcoming) Griffon NVG Head-Up Display (HUD).

SECTION FOUR – NRC FLIGHT TRIALS

4.1 PURPOSE

The NRC Flight Trials were to assess a COTS speech recognition technology, the Verbex Speech Commander, in a Bell 412 cockpit in support of work at the FRL of the NRC. The results of this evaluation will aid in the feasibility assessment of the use DVI in the Griffon cockpit.

4.2 METHODOLOGY: PARTICIPANTS, FACILITY AND PROCEDURE

To allow comparison of this technology in a helicopter with previous work performed on a fixed-wing aircraft at WPAFB (Williamson *et al*, 1997 [Reference 5]), it was decided to utilize the grammar (syntax and vocabulary) from the previous study. The general methodology followed during this experiment was similar to that in the WPAFB study, in that participants read commands into the speech recognition system from a small display. This study varies from the WPAFB work in two ways in addition to the change of aircraft type. First, the participants in this study flew the aircraft while performing the speech recognition task, while in the WPAFB work, the participants rode as passengers in the rear of an OV-10 aircraft. Second, in this experiment the flight profiles varied with respect to operator workload and noise levels, while the WPAFB study varied flight profiles with respect to the physical loading, i.e. g-forces and noise levels. Four flight profiles were investigated:

- a. **On Ground, in Hangar.** Pilots sat in the aircraft on the ground, with the aircraft on ground power (no engines running).
- b. **High Hover.** Pilots maintained a high hover (50 ft) over a test range, using pylons as guides to maintain position and minimize drift.
- c. **Transit.** Pilots flew from the test range to the confined area at 80 knots and 1500 ft.
- d. **Confined Area Hover.** Pilots maintained a low hover (15 ft) in a confined area, surrounded by trees, with position information provided by the safety pilot as necessary to avoid drift into obstacles.

All pilots flew the aircraft, a Bell 412, from the left seat, with a NRC test pilot flying as safety pilot in the right seat. The safety pilot maintained communications with Air Traffic Control, as required. The prompts were presented to the participants on a small LCD, mounted under the glare shield on the instrument panel. Phrases were presented at 7 to 8 second intervals, and pilots were provided with an auditory cue through the headset when a new phrase was presented on the LCD. Noise cancelling microphones were used during the generation of voice templates and data collection. The speech input was provided to the recognizer through the helicopter ICS. All training and data collection sessions were recorded on DAT to allow post trial analysis.

The six participants in this study were CH 146 Griffon pilots from 400 and 427 Squadrons. Four of the six participants participated in the experiment described in Section 3, two participated in DCIEM's DVI study (Farrell *et al*, 1999 [Reference 4]), and one individual had no previous DVI experience.

The COTS equipment used in this study was a Verbex Speech Commander. A speaker-dependent system, the technology requires a voice template be generated by each user. Template generation has two phases: word enrolment and phrase training. Word enrolment presents each word in the vocabulary to the user and generates the basic pronunciation template. Phrase training prompts the user to repeat valid phrases, as defined by the grammar, to incorporate inter-word effects into the template. The generation of voice templates was conducted at a personal computer installed in the cabin area of the helicopter. Pilots used the headset and microphone to be used during the data collection phase to perform template generation. A schedule for the one-day experiment is presented in Table 4-1.

Table 4-1 Experiment Schedule for NRC Flight Trial

Time	Activity
0830	Arrival, Introductions, Briefing on Experiment
0845	Word Enrolment, first pass of phrase training
0930	Break
0940	Initial assessment of recognition accuracy (to provide feedback to the participant)
1000	Second pass of phrase training
1045	Familiarity flight Preliminary assessment of recognition accuracy (in hover)
1120	Third pass of phrase training or individual word re-enrolment, as necessary
1200	Lunch
1300	Data Collection Flight High Hover Transit Confined Area Hover
1400	Data Collection Hangar Condition
1430	Questionnaire and Video Recorded Debriefing

4.3 PRELIMINARY RESULTS

The preliminary results are presented in Table 4-2. The error rates are averaged across the six participants in the study. Both word and phrase error rates were calculated, to allow examination of data where the Verbex system recognized a valid phrase (according to the grammar) that did not match the phrase presented on the screen. As shown Table 4-2, the overall phrase error rate is 6.4%, i.e. the system had an accuracy of 93.6%. Initial review of the data suggests that the error rate is biased by the performance achieved by the individual with no previous DVI experience, i.e. his error rate is substantially greater than any of the other individuals involved, inflating the overall phrase error rate.

Table 4-2 Preliminary Results of the NRC Flight Trials

Error Rate	Percentage
Overall Phrase Error Rate	6.4 %
Overall Word Error Rate	2.2 %
Word Error Rate – Hangar Condition	0.3 %
Word Error Rate – High Hover Condition	2.4 %
Word Error Rate – Transit Condition	2.7 %
Word Error Rate – Confined Area Hover Condition	3.2 %

Further analysis of the collected data will be performed by Mr. Carl Swail of the FRL. It is anticipated that the results of his analysis will be available by the end of September, 2000.

4.4 CONCLUSIONS

The preliminary results suggest that COTS speech recognition technology is sufficiently robust to function in a challenging, high noise environment such as a helicopter. Further conclusions will be presented in Mr. Swail's documentation of these activities when the data analysis is complete.

SECTION FIVE - CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The development of supplemental speech recognition technologies, such as those being investigated at WPAFB, should be monitored. As the technology matures, it should be considered as a component of any future DVI system (Subsection 2.2.2).

The results of the literature survey lead to the conclusion that little work has been conducted to date on the development of an OI for aircraft DVI systems. The majority of the aircraft studies have focused on recognition technology and accuracy (Subsection 2.2.3).

It is concluded that a DVI system has the potential to enhance flight safety and mission performance for crew in the CH146 Griffon. The OI assessment has shown that the proposed DVI system can have a positive and significant impact on the performance of CH146 Griffon crew. In particular, relative to the current MI configuration, DVI was shown to substantially reduce the NFP head-down time (Subsections 3.2.4.2 and 3.3.3.1). This resulted in faster and more accurate detection of visual targets in the external scene for the NFP (Subsection 3.3.3.2.1).

Generally, the combination of auditory tones and visual feedback of the commands was judged to be effective (Subsection 3.2.4.1.2). It is not clear, however, whether auditory feedback should be extended to include not only tones, but also voice (e.g., computer-generated repetition of the input) and further research should be conducted.

The results of the OI evaluation lead to the conclusion that the FPs allocated attention toward the DVI system (Subsection 3.3.3.2.2). This allocation may have occurred because the FPs had the capability to manipulate cockpit systems with DVI through commands and/or because the FP had ready access to information regarding cockpit systems, as provided by the DVI system, i.e. through feedback. Allocation of attention toward the DVI system may have a negative impact on the FPs performance on other tasks.

The pilots in the OI study were able to remember and use the set of DVI commands effectively. Several pilots noted that a DVI system would be especially useful when NVGs are used in the Griffon.

The preliminary results from the NRC Flight Trials suggest that COTS speech recognition technology is sufficiently robust to function in a challenging, high noise environment such as a helicopter cockpit (Subsection 4.3).

5.2 RECOMMENDATIONS

It is recommended that the CH146 DVI OI, described in Annex E, be further developed to a pre-production level. It is recognized that improvements are required and these must be addressed in the final design effort.

Specifically, it is recommended that:

- a. further study of the CRM issues related to DVI cockpit integration be conducted. Research should be undertaken to understand the interaction between the FP and the DVI system in the modified CRM implemented in the present study. Additionally, the integration of DVI into the current Griffon CRM, eliminating the FP's ability to interact with the system, should be investigated. In particular, the impact of DVI on the FP's workload and reaction time should be considered;
- b. the control set be expanded. The addition of new commands to accommodate additional cockpit functions or provide alternatives to existing commands should be explored. A potential application would be to modify the command set so that the DVI system could be used to change pages and symbology on the (forthcoming) Griffon NVG HUD;
- c. alternative feedback methods be studied. In particular, voice feedback, which would allow the user to enter a command and receive detailed feedback while not looking at a DVI feedback display or the CDU should be investigated; and
- d. alternative COTS speech recognition technology should be assessed to identify the system best suited for this application.

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ANNEX A - GLOSSARY OF TERMS AND ACRONYMS

ABCCC	AirBorne Command and Control Centre
AC	Aircraft Captain
ACD	Aircraft Crewstation Demonstrator
ACO	Air Control Order
ACP	Air Control Point
AFCS	Automatic Flight Control System
AFRL	Air Force Research Laboratory
AGC	Automatic Gain Control
AGL	Above Ground Level
AMS	Avionics Management System
ANOVA	ANalysis Of VAriance
ANR	Active Noise Reduction
AOI	Aircraft Operating Instructions
ASE	Aircraft Survivability Equipment
ASR	Automatic Speech Recognition
ATO	Air Tasking Order
AUW	All-Up-Weight
AWACS	Airborne Warning And Control System
BDA	Battle Damage Assessment
BSC	BAE SYSTEMS CANADA INC.
CDU	Control and Display Unit
CEOI	Communications - Electronics Operating Instructions
CF	Canadian Forces
CFB	Canadian Forces Base
CHS	Centre for Human Sciences
CMC	Canadian Marconi Company
COGPIT	COGnitive CockPIT
Comm	Communications
COTS	Commercial Off-The-Shelf
CRM	Crew Resource Management
CSAR	Combat Search And Rescue
CSC	Communications System Console
D/NAW	Day, Night and All Weather
dB	deciBel
DCIEM	Defence and Civil Institute of Environmental Medicine
DERA	Defence Evaluation and Research Agency
DND	Department of National Defence
DNMD	Digital Navigation Map Display
DSRS	Digital Speech Recognition Software
DTU	Data Transfer Unit
DVI	Direct Voice Input

EMG	Electro-MyoGraphy
ERSTA	Electro-Optical Reconnaissance, Surveillance and Target Acquisition
ETA	Estimated Time of Arrival
FAC	Forward Air Control
FARP	Forward Ammunition and Replenishment Point
FE	Flight Engineer
FEBA	Forward Edge of the Battle Area
FFS	Full Flight Simulator
FM	Frequency Modulation
FO	First Officer
FOV	Field-Of-View
FP	Flying Pilot
ft	feet
GPS	Global Positioning System
GUI	Graphical User Interface
HCCR	Hot Closed Circuit Refuelling
HFE	Human Factors Engineering
HMD	Helmet Mounted Display
HOCAC	Hands-On Cyclic And Collective
HSI	Horizontal Situation Indicator
HUD	Head-Up Display
HVQK	HaVe QuicK
Hz	Hertz
ICAO	International Civil Aeronautical Organization
ICS	InterCommunications System
IFF	Identification Friend-or-Foe
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IP	Initial Point
IR	InfraRed
JAOC	Joint Air Operations Centre
JSTARS	Joint Surveillance Target Acquisition Radar System
KHz	KiloHertz
KIAS	Knots Indicated Air Speed
km	kilometre
kt	knot
LATEF	Land Aviation Test and Evaluation Flight
lb	pound
LCD	Liquid Crystal Display
LPT	Layered Protocol Theory

LRN	Long Range Navigation
LZ	Landing Zone
MAWS	Missile Approach Warning System
Mb	Megabyte
MC	Mission Commander
MI	Manual Input
MGRS	Military Grid Reference System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
Nav	Navigation
NFP	Non-Flying Pilot
NOE	Nap-Of-the-Earth
NRC	National Research Council
NVG	Night Vision Goggles
OI	Operator Interface
OP	Observation Point
OTW	Out-The-Window
PC	Personal Computer
PCT	Perceptual Control Theory
PPOS	Present POSition
PTR	Press-To-Recognize
PTT	Push-To-Talk
PWGSC	Public Works and Government Services Canada
PZ	Pick-Up Zone
recce	reconnaissance
ROZ	Restricted Operating Zone
RP	Release Point
RT	Response Time
RWR	Radar Warning Receiver
SAM	Surface-to-Air Missile
SAS	Stability Augmentation System
SCREAM	Speech and Communication Research, Engineering Analysis and Modelling
SGI	Silicon Graphics International
SITREP	SITuation REPort
SME	Subject Matter Expert
SOP	Standard Operating Procedures
SUI	Software User Interface
TI	Thermal Imager

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UK	United Kingdom
UTM	Universal Transverse Mercator
UTTH	Utility Tactical Transport Helicopter
VACP	Visual, Auditory, Cognitive and Psychomotor
VCR	Video Cassette Recorder
VFR	Visual Flight Rules
WPAFB	Wright-Patterson Air Force Base

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**ANNEX B
SITE VISIT REPORTS**

31 Aug 00

ANNEX B - SITE VISITS REPORT

B.1 CFB GAGETOWN TRIP REPORT

As part of the System Analysis phase of the Development of Direct Voice Input Control for the Griffon Helicopter project, BAE SYSTEMS CANADA INC. (BSC) (formerly Canadian Marconi Company (CMC)) conducted a site visit to Canadian Forces Base (CFB) Gagetown - specifically the Land Aviation Test and Evaluation Flight (LATEF). The purpose of this visit was to gain an understanding of the workload issues associated with the tactical environment, in particular the use of Control and Display Units (CDUs) in the low-level environment and during night operations with and without Night Vision Goggles (NVGs). As such, BSC worked with LATEF to establish a visit schedule that would facilitate access to flight crews and facilities (CH146 flight simulator, etc.) and participation in tactical training flights.

Representing BSC on this visit were Mr. Murray Gamble in the capacity of Project Engineer and Mr. Michael Wellwood as a CH146 Domain Expert. Dr. Philip Farrell, Scientific Authority for the project, accompanied Mr. Wellwood and Mr. Gamble during the visit. The agenda for the week is documented in Table B-1.

Monday was originally planned as a day for introductions and for the exchange of information on activities underway at BSC (then CMC), DCIEM and LATEF. This original schedule was appended to include the mission planning and execution of a tactical training mission. This change in plans was precipitated by uncertainties about the weather forecast for the balance of the visit. Since the observation of activities during night missions using NVGs and associated data collection was deemed to be a critical component of the site visit, LATEF suggested that everyone take advantage of the weather while it lasted.

Mr. Gamble presented an overview of the CH146 DVI project and provided some background on previous DVI-related work that had led up to the nexus of this project. Dr. Farrell presented an overview of DCIEM and previous CH146 related projects. Capt. Whitaker then briefed the group on LATEF's ongoing activities, including the evaluation of the Digital Navigation Map Display (DNMD) and procurement of an NVG-compatible exterior lighting system for the Griffon.

Capt. Whitaker led the group through the development of a mission scenario that would allow everyone to observe the most challenging and workload-intensive phases of a CH146 tactical mission. Capt. Whitaker proposed a mission that combined a number of challenging elements including ongoing communications with three external agencies, preparation and transmission of contact reports, IFF code rotations at thirty-minute intervals, and a mission re-tasking to assist in a Combat Search And Rescue (CSAR) effort. The mission was concluded with a simulated flight into inadvertent Instrument Meteorological Conditions (IMC) and an Instrument Flight Rules (IFR) recovery and approach into the Fredericton airport.

Throughout this flight, the actions and utterances of the crew were being captured via a video camera fitted with light amplification equipment.

Table B-1 Agenda for Canadian Forces Base Gagetown Trip

Day	Activity(ies)
Monday, 1 March 1999	• Provided an introductory briefing on the goals of the project and on specific goals of our site visit. • Participated in a briefing by Dr. Farrell on Defence and Civil Institute of Environmental Medicine (DCIEM) activities related to the CH146 community. • Participated in a briefing given by Capt. Lou Whitaker on current LATEF activities. • Participated in mission planning exercise with Capt. Whitaker. • Observed night tactical training mission.
Tuesday, 2 March 1999	• Organized and participated in a Direct Voice Input (DVI) brainstorming session with Capt. Whitaker and Maj. Jerry Demetriadis. • Participated in Crew Resource Management (CRM) analysis and awareness familiarization in the CH146 Full Flight Simulator (FFSs).
Wednesday, 3 March 1999	• Attended meteorological briefing. • Attended Air Mobile training mission pre-flight brief. • Observed simulated Air Mobile training mission.
Thursday, 4 March 1999	• Participated in the planning of an Aircraft Survivability Equipment (ASE) training exercise to be executed in the CH146 FFS. • Observed ASE training exercise in the CH146 FFS.
Friday, 5 March 1999	• Wrap-up briefing.

On Tuesday morning, a discussion group was assembled comprising Capt. Whitaker, Capt. Tikka, Maj. Demetriadis, Dr. Farrell, Mr. Wellwood and Mr. Gamble. The goal of this discussion group was to brainstorm on issues associated with the implementation of a DVI system in a crewed environment. We employed the mission scenario from the previous evening, as well as the videotaped footage of the flight to stimulate the discussion of implementation issues. Capt. Whitaker raised the group's awareness of potential flight safety implications associated with voice control being applied to flight critical operations (i.e. control of the Automatic Flight Control System (AFCS)). Maj. Demetriadis expressed his interest in the applicability of DVI in high workload situations where both flying and non-flying pilots were saturated. He also expressed some concerns regarding the deploying and maintainability of a speaker-dependant speech recognition system that would require a user to transfer a voice

"template" to the aircraft. The result of this working group discussion was the conceptualization of a system that attempted to complement the current CRM model of the Griffon cockpit.

Tuesday afternoon was spent in the CH146 FFS facility. Mr. Wellwood, under the supervision of Capt. Tremblay, facilitated a familiarization with the flight simulator and provided Dr. Farrell and Mr. Gamble the opportunity to become more familiar with the mechanics of CRM in the Griffon cockpit. To this end, Mr. Wellwood took Dr. Farrell and Mr. Gamble through numerous scenarios that placed us in high workload situations much like those observed during the previous evening's mission. In addition, Dr. Farrell and Mr. Gamble were introduced to some of the challenges of flight operations using NVGs.

Wednesday morning was spent on a meteorological brief as an introduction to the day's activities. This brief was followed by another, during which we observed the planning of a training exercise that involved a multiple aircraft troop transportation mission or "Air Mobile". Shortly thereafter, we participated in the Air Mobile as observers. The crew activities during this mission were recorded using an overhead "lipstick" camera. This camera allowed us to capture the CDU specific interactions throughout the mission. However, due to an unfortunate technical complication, the audio component of the mission was lost.

Wednesday afternoon was spent in the 403 Squadron hangar facility collecting data on cockpit dimensions and discussing potential options for DVI hardware (feedback display, etc.) placement. This was also used as an opportunity to record some dimensions and take photographs of the cabin area. The latter information was deemed important to the Electro-Optical Reconnaissance, Surveillance and Target Acquisition (ERSTA) project.

Thursday was spent in the FFS facility with Maj. Demetriadis and Capt. Cybanski. The goal for that day was to recreate and document high workload mission elements that could not be effectively simulated in real aircraft (i.e. Aircraft Survivability). Mr. Wellwood, Dr. Farrell and Mr. Gamble spent the morning with Maj. Demetriadis and Capt. Cybanski planning and discussing the missions that would be flown in the FFS that afternoon. In order to facilitate data collection, LATEF personnel installed two video cameras in the simulator. This provided an excellent capability to capture both CDU specific interactions as well as overall crew activities and Out-The-Window (OTW) information. The FFS InterCommunications System was connected to the VCRs capturing the video, so that all relevant audio information could also be captured. During the simulated missions, the crew was tasked with a recce-type mission that required a large amount of radio communications in the form of SITuation REports (SITREPs), as well as radio communications with other agencies. Throughout the missions the crew was exposed to numerous air- and ground-based threats that required tight crew coordination and a flurry of cockpit activity. It was clear that the information being captured was going to be invaluable in demonstrating the high level of activity that is achieved in the CH146 cockpit and in identifying the specific activities whose execution could be greatly assisted through the application of DVI. During the post-flight briefing Capt. Cybanski pointed out that there were numerous occasions where he thought that a DVI system that would allow him to manipulate the radios while allowing him to maintain an "eyes-out" posture (i.e. watching for threats/contacts) would have been extremely helpful.

The last day of the Gagetown site visit (Friday) included a trip de-brief at which time Mr. Gamble summarized the process that BSC would be following to analyze the data collected

during the visit. Mr. Gamble also provided an overview of the project schedule and tentative dates for the Aircraft Crewstation Demonstrator (ACD) DVI experimental trials. LATEF expressed an interest in participating in the trials and an invitation was extended to them to assist in the pre-trial exercises. It was thought that this would be a good point for LATEF to be involved so that they would have a chance to evaluate the systems and provide feedback prior to the trials. LATEF would also be able to provide valuable assistance towards the validation of the mission scenario around which the trials were based.

B.2 DERA TRIP REPORT

The Defence Evaluation and Research Agency (DERA) visits provided an opportunity to fulfil a contractual obligation to investigate DVI research being conducted at scientific centres of excellence. Dr. Philip Farrell of DCIEM accompanied Mrs. Laura Lynne Churchill of BSC on this visit. In addition to learning about DERA's DVI research, Dr. Farrell took advantage of the visit to work with Dr. Bob Taylor and his group on the COGNitive CockPIT (COGPIT) project.

The week's activities entailed a visit to two DERA sites. Monday, Tuesday and Friday were spent at DERA Farnborough, home to the Centre for Human Sciences. Wednesday was spent at DERA Malvern, where research is grouped into four major areas: Command and Information, Electronics, Land Systems, and Sensors and Processing. A short visit was also made to Smiths Industries in Cheltenham. The agenda for the week is detailed in Table B-2.

Table B-2 Agenda for Defence Evaluation and Research Agency (DERA) Trip

Day	Activity(ies)
Monday, 6 December 1999	Briefing with Bob Taylor and Graham Rood's group on DVI and other research activities.
Tuesday, 7 December 1999	- Briefing on COGPIT. - Working session (with Dr. Philip Farrell, Ms. Rosie Dru-Drury, Mr. Alex Connell, and Mrs. Laura Lynne Churchill) exploring the use of DVI in a fast-air scenario.
Wednesday, 8 December 1999	- Briefing with Mr. Martin Taylor and Mr. Robert Seares regarding speech recognition technology research. - Meeting with Mr. Peter Jones at Smiths Industries regarding DVI in the Eurofighter Project.
Friday, 10 December 1999	Cognitive Engineering Awareness Day.

Monday was an exchange of information regarding DCIEM and DERA's research activities. The focus was on DVI, but other research projects at DERA were discussed. Dr. Farrell presented an overview of DCIEM and previous CH146 DVI work, and Mrs. Churchill then presented the preliminary results from the ACD experiment. Dr. Rood provided a briefing on his group's activities.

The Aircraft Systems Group, headed by Dr. Rood, focuses on the development and integration of new technology into the cockpit. Current projects include:

- a. next generation ejection seats, with an active control system;
- b. noise surveys in operational aircraft during real missions;
- c. auditory warning design and implementation;
- d. anthropometrics;
- e. helmet bio-mechanics;
- f. wide field-of-view (100°) NVGs;
- g. new display technologies; and
- h. eye-tracker systems for bright sunlight conditions.

A demonstration of their advance control technologies laboratory where eye-tracking was used to activate virtual instruments displayed on a Helmet Mounted Display (HMD) was provided. In addition, DVI was demonstrated as a means of switching between manual and automatic flight modes.

Mr. Paul Collins and Mr. Alan South spoke in more depth about the DVI work being conducted at Farnborough. Mr. South's work has been based primarily in the fast-air (single pilot cockpit) world. He identified several challenges facing the integration of DVI into the cockpit: pressure breathing, Active Noise Reduction (ANR), cockpit noise, and g-load being the primary concerns. Two technologies, Electro-MyoGraphy (EMG) and optical lip-reading, have been proposed as supplements to the recognition algorithm in order to improve accuracy.

Based on flight trials conducted in the Tornado (1993), DERA has developed a database of voice recordings and aircraft ambient noise. This has allowed them to simulate the aircraft environment and effectively evaluate speech recognizers in a laboratory setting. Mr. South is currently evaluating the Verbex system. His preliminary results suggest, at best, a recognition rate of 95%; however, he is still manipulating the configuration of the hardware/software and is hoping to achieve better results.

Mr. Collins's work has been directed more to the rotary wing environment. Flight trials conducted in a Lynx using the AURIX system yielded recognition rates ranging from 85% (with a single pass of training) to 99% (with embedded training). It should be noted that a "quick reference" card was provided to the participants in this study to aid their recall of the syntax. A particular challenge with the Lynx helicopter is the natural frequency of the aircraft - 22 Hz. This frequency happens to coincide with the natural frequency of the larynx, generating interference in speech production.

A unique recommendation regarding the training of the system was offered, and should be considered for any future experimental DVI work. Mr. Collins found nearly 100% recognition accuracy if the users were trained in an embedded environment. As an example, in a recent study, the participants trained the speech recognizer while playing a flying video-game.

The second day of the visit to Farnborough was centred on the COGPIT project. Dr. Taylor provided a briefing to Dr. Farrell and Mrs. Churchill on the project and the progress to date. This was followed by a tour of the group's simulation facility, similar to the ACD at BSC. After gaining an appreciation for the simulation environment, a working group was held to

examine the role of DVI in the COGPIT. A mission scenario had been developed and was used as the basis for the discussion. The functions conducted during each mission segment were examined and several segments were identified as containing functions suitable for a DVI interface.

Wednesday Dr. Farrell, Mrs. Churchill, and two members of CHS (Rosie Dru-Drury and Ritva Eriksson) travelled to DERA Malvern (located about two hours to the north-west). Mr. Martin Abbott, our host, presented his research that included speech recognition, speech input/output, paralinguistic analysis, speech processing and Markov modelling. In November, this DERA lab had recently joined with industry and have started a new company called 2020Speech (<http://www.2020speech.com/index.html>). They will compete directly with companies such as Dragon Systems.

AURIX is the speech recognition system and the backbone of their work. It was originally designed as a rapid, speaker dependent prototyping tool. It now has the capability of being used in either speaker independent or dependent modes. There is progress being made in trying to improve recognition rates in noisy and vibrating environments, as well as changes in voice pitch. Interestingly, Mr. Abbott is looking at training the speech recognizer, which would recognize phonemes rather than words.

Mr. Robert Seares also talked about a series of trials they performed in a Challenger II armoured vehicle. He used speaker-independent technology knowing that there would be many users of the system. He also demonstrated a speaker independent system with natural continuous speech input that was used to train ATC controllers. Both Mr. Abbott and Mr. Seares were disappointed to hear that the speech recognizer development by the National Research Council (NRC) and BSC (then CMC) had ceased, and Canada had opted to look for off-the-shelf solutions.

On the return journey to Farnborough, the group stopped at Smiths Industries and spoke with Mr. Peter Jones, Business Development Manager. Smiths Industries has developed and integrated a hardened DVI system for the Eurofighter aircraft. While the system has been integrated into the simulator, it is not to be tested in the aircraft in the near future. Unfortunately, we were unable to speak with Alison Starr, the human factors expert within the project at Smiths. However, based on information from Dr. Farrell and Mr. Jones, it appears that the majority of the syntax was developed by British Aerospace (now BAE SYSTEMS). It may be appropriate during the next iteration of Griffon DVI to talk with the group within BSC responsible for DVI in the Eurofighter.

The last day of the visit was a Cognitive Engineering Awareness Day. This half-day event consisted of nine (9), 15 to 20 minute presentations by various members of Dr. Taylor's group describing their current projects. Topics included implicit situational awareness, a cognition monitor, and military maintenance. The session provided a good summary of the work being conducted by the group.

B.3 Air Force Research Laboratories, Wright-Patterson Air Force Base Site Visit

The Air Force Research Laboratories (AFRL), Wright-Patterson Air Force Base (WPAFB) visit provided an opportunity to fulfill a contractual obligation to investigate DVI

research being conducted at scientific centres of excellence. Dr. Philip Farrell of DCIEM accompanied Mrs. Laura Lynne Churchill of BSC on this visit.

The one-day visit was an exchange of information regarding the Defence and Civil Institute of Environmental Medicine's (DCIEM) and AFRL's research activities in DVI. Dr. Farrell presented an overview of DCIEM and previous CH146 DVI work. Mrs. Churchill then presented the preliminary results from the ACD experiment and NRC flight trials. Mr. Dave Williamson was most interested to learn of the results from the NRC Flight Trials with the Verbex Speech Recognizer, as he had assessed this technology in an experimental F-16 and wished to compare the results.

Dr. Timothy Anderson and Mr. Dave Williamson, members of the Speech and Communication Research, Engineering Analysis and Modelling (SCREAM) laboratory, gave a briefing on current DVI projects. The majority of ongoing research activities focus on developing techniques to supplement traditional speech recognition algorithms. To accomplish this goal, the laboratory is generating models of human speech production and perception. Techniques that are under development based on this research include binaural speech processing, optical lip reading, the use of EMG data from facial and neck muscles (in co-operation with Alan South of DERA and Bernie Hudgins of University of New Brunswick), and laryngographs.

The other major undertaking of the SCREAM lab is the assessment of Commercial Off-The-Shelf (COTS) recognizers for different aircraft environments. The current product under study, Nuance, is showing promise for the demanding cockpit environment, achieving 97 to 98% accuracy for the F16.

Mr. Williamson also discussed a recent project which compared the use of DVI with traditional data entry means (keyboard, mouse) in an Joint Air Operations Centre (JAOC) for the generation of Air Tasking Orders (ATOs). The computer-based tool used to generate ATOs was recently redesigned and DVI was added as an alternative input device. Because of the departure from the previous software, users assessing DVI were "novices" with both DVI and more traditional input devices. Since users had equivalent experience levels with the two input modalities, it was easier to assess the benefits of DVI, e.g. DVI was not being compared against a well learned system. In general, the users felt the DVI system to be superior to the traditional input mode and were quite accepting of the technology. Mr. Williamson will be presenting a paper on this work at the International Ergonomics Association/Human Factors and Ergonomics Society 2000 meeting in San Diego at the beginning of August.

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**ANNEX C
LITERATURE SUMMARY**

31 Aug 00

ANNEX C - LITERATURE SUMMARY

C.1 GENERAL

This annex provides an informal summary of the documents retrieved during a literature search for the Griffon DVI Project. This document was developed as an aid for other members of the Direct Voice Input (DVI) project group and the Human Factors Engineering (HFE) Team during the development of the DVI syntax and feedback. For the document to be of the most use to the team members, each paper was summarized individually, grouped by general research area.

The search was limited to references discovered using web-based meta- and regular search engines (e.g. MetaCrawler, Northern Lights, Lycos, AltaVista). Phrases commonly used for the web searches were:

- a. Direct Voice Input (DVI);
- b. speech input;
- c. speech recognition;
- d. cockpit design;
- e. interface design;
- f. feedback design;
- g. human factors;
- h. auditory feedback;
- i. helicopter cockpit; and
- j. visual feedback.

Note: this is not an exhaustive list.

The remaining references were selected from the extensive list developed by Defence and Civil Institute of Environmental Medicine (DCIEM) during the preparation for their DVI experiment.

C.2 SIMULATOR STUDIES

C.2.1 Female Voice Communications in High-Level Aircraft Cockpit Noises - Part II: Vocoder and Automatic Speech Recognition Systems [Reference 6]

This is the second paper describing a four-part study examining the differences between male and female speech. The first paper examined the effects of cockpit noise and noise-cancelling microphones on speech intelligibility. This paper examined the intelligibility of vocoded speech and the accuracy of speech recognition systems. The speech recognition study was conducted in a sound booth and used standard Air Force InterCommunications System (ICS) equipment. The vocabulary was the same used by Williamson, Barry, and Liggett (1997) [Reference 5] in their aircraft-based speech recognition study. Ambient noise from two aircraft, a C130E and a MH53, were recorded on a DAT and presented over speakers in the sound booth at four levels (66, 95, 105 and 115 dB) during the experiment. Two speech recognition systems were compared: an ITT VRS-1290 and IBM's VoiceType, both installed on a PC. The

participants wore an H-157 headset and used an M-162 microphone for the data collection. Each experimental trial was recorded on a DAT; the "live" input was fed to the ITT VRS-1290 card and the DAT was used to provide the input for the IBM system. There were no significant differences based on gender for either the C130E or the MH53. The recognition accuracy for the MH53 was very low – at 66 dB (the baseline) recognition rates were only 81%; at 115 dB, the recognition rates were 3 to 8%! Why the recognition rates are so low is not clear from the paper: the recognition system was trained by all users under all noise conditions before data collection began.

C.2.2 The Application of Direct Voice Input to Battlefield Helicopters [Reference 7]

This paper reports on the integration of DVI into the helicopter cockpit as part of the United Kingdom's (UK) Day, Night and All Weather (D/NAW) programme. The speech recognition system used in the study (AURIX) was developed by the Defence Evaluation and Research Agency (DERA) and is activated by a Press-To-Recognize (PTR) button on the collective. To enhance the realism of the simulator, the helicopter cockpit was fitted on a 3-axis vibration platform. The study compared the use of manual controls and DVI by a pilot and commander during Nap-Of-the-Earth (NOE) missions in a simulated operational environment. Four missions were flown (attack, Air Operations, recce, and battle plan delivery) by five crews, all of whom were Lynx pilots or Rotary Wing Test Pilots. The order of mission types and DVI/Manual controls were determined by a Latin Square design. The pilot controlled the Helmet Mounted Display (HMD) symbols while the commander controlled the radios (frequency, cipher, transponder standby/transmit, normal/emergency, and transponder code) and moving map display (scale and orientation). Dedicated vocabularies were generated and trained for both the pilot and commander. Feedback was provided to both participants through talk-back over the headset. The sessions were video recorded to capture the following information: pilot's HMD, Commander's Target Indicator display, moving map/radio control panel display, camera view of command and displays/controls. Three logs were recorded to track mission/operational data, helicopter data and position data throughout the flight. Situational awareness and workload measures were collected immediately after the trial. No results other than participants' comments are reported in the paper. In general, most participants liked the system; indeed, several asked that additional controls such as anti-collision lighting, windshield wipers, and multi-page displays be added. The research for this paper was done in preparation for flight trials in the Lynx to be conducted in August/September 1997.

C.2.3 The Effects of Speech Controls on Performance in Advanced Helicopters in a Double Simulation Paradigm [Reference 8]

The study examined the effect of response modality on time-sharing performance. The experiment was performed in the NASA-Ames' Interchangeable Cab facility; the aircraft simulated was a single-pilot scout/attack helicopter. The mean flight time in a helicopter for participants was 2921 hours. The participants wore Head-Up Displays (HUDs) (collimated to optical infinity) which displayed the following information: attitude, heading, torque, airspeed, altimeter, instantaneous vertical speed, skid indicators, and targeting pipper for the helicopter's weapons. An aircraft-up moving map display was used to navigate the 4 kms by 4 kms terrain data base. An experiment consisted of two five-minute flights, each flight consisting of six

phases. Each session lasted approximately one hour, i.e. a pilot would fly six experiments per session, and participants completed one practice and four data collection sessions. The experiment compared the interference of manual and speech responses during continuous flight control and altitude-hold automation manipulation. A secondary "probe" task was used to evaluate the interference. One of two possible threats (SAM-6 or SAM-9) was presented to the pilot; one (SAM-6) required a manual response (depress button on cyclic) while the other (SAM-9) required a voice response ("Flare"). The presentation of the threats occurred during any two of the three flight phases (i.e. hover, transit, or combat) during each flight and was manipulated within flights. In order to provide a more detailed analysis of the (predicted) interference, a Psychological Refractory Period Paradigm was used. The helicopter unexpectedly pitched down and rolled, and the pilot was to bring the aircraft to the previous altitude and attitude as quickly as possible. Either 100 or 300 milliseconds after the aircraft pitched and rolled, the pilot would be presented with one of the two threats and the reaction time to the threat was recorded. Subjective ratings were obtained from each participant after each session. The combination of countermeasure conditions within a flight and order of the six flights per session was randomized under the constraint that for each set of three flights, each threat condition (SAM-6, SAM-9, no threat) was presented once during the combat phase. The order of the automation manipulation was counter-balanced across subjects. The single task Response Time (RT) for response modality was significantly slower for the speech than manual control. To evaluate the hypothesized interference, the decrement in performance was calculated and compared. A Phase (combat, hover, cruise) x Response (voice, manual) x Automation (none, altitude-hold) repeated measures ANalysis Of VAriance (ANOVA) was performed for the decrement scores which had been averaged across all sessions. There was a significant main effect of flight phase on the RT decrements for the cruise, hover and combat segments. In addition, a significant flight phase x response modality interaction occurred ($F(2,18)=3.78, p<0.05$). In the psychological refractory period section of the experiment, there was a significant modality x inter-stimulus interval interaction ($F(1,9)=21.82, p<0.001$).

C.2.4 Voice versus Manual Techniques for Airborne Data Entry Correction [Reference 9]

The first section of the paper provides a good summary of the DVI work done to date (1991). In the study described in this paper, participants performed a visual tracking task on a HUD using the flight stick in a cockpit simulator to provide control inputs. Subjects were tasked to repeat digit strings presented on the HUD into their microphone and assess the visual feedback on a Liquid Crystal Display (LCD) readout. The input mode for data correction, DVI (Marconi Macrospeak ASR) or keypad, was assessed across groups (two groups of ten). Twenty-four digit strings were presented to each participant during the experiment. A training session preceded the experimental run; when the experiment was complete, participants provided subjective ratings (NASA TLX). Participants' performance was measured by tracking accuracy, average tracking error, correction times and post correction error frequency. A multivariate analysis of the performance measures showed a difference between voice and keypad on the combined dependent variables ($p=0.07$). A repeated measure of analysis of covariance was performed for correction times to examine error type (insertion, substitution, rejection) and string length. Keypad correction times were shorter in duration ($p=0.002$); the interaction of DVI x error type showed keypad correction was faster on rejection, substitution, and insertion errors ($p=0.000$). An interesting idea was presented in the discussion: "Human resource compatibility theory may

be involved when considering cursor movements required for correction. It could be argued that tracking cursor movement is essentially a spatial tracking task, so resource compatibility theory suggests that this would be more suited as a manual task whereas correction command themselves would be more effectively done by voice."

C.3 REVIEW PAPERS

C.3.1 Applications of Speech Based Control [Reference 10]

This paper summarizes the work done to date (1998) on speech recognition in the aerospace environment, identifies problems that may hinder the integration of speech recognition in aerospace applications, and identifies enhancements that may allow speech recognition to be used effectively in harsh environments. The study of speech recognition in fixed-wing aircraft began as early as 1982 in civil airliners. Most of the work done to date has focused on the technical aspects, i.e. recognition performance, in the harsh environment. The exception is the EuroFighter 2000 which has integrated speech control from the initial design phase. Although the speech recognition system has not yet been installed in the aircraft, significant work has been done in the simulator to develop the interface. Rotary-wing studies have demonstrated that the largest problem to overcome in the helicopter cockpit is the high noise level during flight. DERA conducted mission-based simulator trials in early 1997. The results showed the pilot used 25 words to control radios and Radalt while the commander (using a different vocabulary) used approximately 45 words to control radios, map displays, transponder and Radalt (Collins et al., 1997) [Reference 7]. MultiHélicare, a real-time digital map generator, has integrated speech recognition and been tested on Gazelle during real flights. The system has been in use for several months, and operators feel the integration of the speech recognition system has decreased their workload. The Canadian Space Agency has studied the use of speech control for the space shuttle manipulator arm, and even though astronauts were not given a fixed vocabulary, only 107 words were used total and 30 of these were common to all speakers. In the late 1980s, the possibility of using speech recognition for command and control, particularly in an Airborne Warning And Control System (AWACS) environment was explored; however, the idea was rejected due to the high stress environment, high recognition accuracy required, and the multiple voice communications occurring in the background. The use of speech recognition to monitor pilots' emotional and physical conditions, while a potential application of speech recognition technology, is a long way in the future. Problems that have hindered the integration of speech input in aerospace applications are noise, pilot stress (physical and psychological) and regional accents. Further research is required to develop speaker-independent systems that will operate effectively (and recognize accurately) in the aircraft cockpit.

C.4 ROTARY-WING STUDIES

C.4.1 Direct Voice Input for Control of an Avionics Management System [Reference 11]

The operator interface evolved through subject matter expert interview sessions and rapid prototypes using a Silicon Graphics workstation and the DVI equipment. The main objective of the operator interface was to produce intuitive voice control that would allow the pilot to be "hands free, eyes out." The communication system used in the helicopter involved a

press-to-talk switch for the intercom and external transmissions. Keyword activation was used to initiate DVI listening mode. The system would stop listening if no words were spoken for 10 seconds, if the pilot said "Stand-by" or the pilot depressed a DVI control switch on the Avionics Management System (AMS). The syntax is described in detail in the paper. The test system consisted of a CMA-2082 AMS, the DVI card, and two ARC 182 radios integrated by a MIL-1553 bus. The ICS was modified to provide the audio input signal to the DVI; however, signal clipping problems were encountered and the headset microphone was replaced with a microphone with a built-in preamplifier (bypassing the ICS preamplifier). Two training sessions per pilot were conducted on the ground in the aircraft. The test flight was conducted as though the evaluation pilot was the sole crewmember. The second pilot acted as a "safety", monitoring airspace and radio frequencies during the flight. There were four phases to the test flight: free-play (to familiarize the operator with the system), verbal rally (following ground staff through a series of frequency changes), aiding a second aircraft simulating an in flight emergency and normal flight (using the DVI as if it were a regular aircraft system). Six pilots (1 National Research Council (NRC), 5 Canadian Forces Griffon) completed the flight trial. Recognition rates ranged from 87.4 to 99.2%; however, this did not include instances where participants used words outside of the syntax. All pilots felt that DVI could assist them in completely high workload tasks (e.g. changing radio frequencies while in a hover). Based on pilots' behaviour, it would seem that some form of (visual) feedback while commands are given should be provided.

C.5 FIXED-WING STUDIES

C.5.1 Flight Test Performance Optimization of ITT VRS-1290 Speech Recognition System [Reference 5]

This paper details Wright Patterson Air Force Base's work on DVI using an ITT Industries (ITT) VRS-1290 recognizer in an OV-10A aircraft. Participants in the study did not fly but rather sat in the rear seat of the aircraft. The test equipment was rack-mounted in the cargo bay of the aircraft. A 486 ISA bus PC hosted the ITT VRS-1290. The same helmets and boom mikes (M-162) were used for all data collection. The vocabulary consisted of 53 words and short phrases, which were combined to form 91 test "sentences." The experiment was a single-factor within subjects design, with five levels of the environment (independent) variable: lab [182 "sentences"]; hangar (no engines running) [182 "sentences"]; 1g1 [182 "sentences"]; 3g [67 "sentences"]; 1g2 (to test for possible fatigue effects) [182 "sentences"]. Many problems were experienced during the first trials - poor noise calibration and ineffective Automatic Gain Control (AGC) are the two that created the majority of problems and are the most likely to pose difficulties in further studies. Although 16 pilots participated in the study, only five had valid real-time recognition performance. A total of 12 (which included the five with real-time data) DAT recordings were successfully created. The recognition rates for the five real-time data were compared against the recognition of their recordings played to the ITT VRS-1290, and no significant differences were found. The remaining seven recordings were then played to the ITT VRS-1290 for recognition and analysis. Three comparisons were of particular interest: Ground (lab + hangar) versus Air (1g1 + 3g + 1g2); 1g (1g1 + 1g2) versus 3g; and 1g1 versus 1g2. No significant differences were found for any comparisons. Signal to noise ratio decreased by 6 dB in the 3g condition. The most important conclusion from the study is to ensure that the audio is of adequate quality. This implies that AGC, signal clipping, ICS, microphones, and pre-amplifiers may be the biggest hurdles to overcome in developing a fielded system.

C.5.2 Flight Test Results of ITT VRS-1290 in NASA OV-10 [Reference 12]

This paper describes the same experiment as the one described in C.5.1 above; however, at the detail level, slightly different information is presented (this report seems to be slightly less formal).

C.6 WORKLOAD**C.6.1 The Effects of Workload on the Use of Speech Recognition Systems [Reference 13]**

Two studies were conducted that examined workload and the impact on speech production and recognition. Two possible types of workload interference were identified: mechanical (physical changes in speech production apparatus) and psychological (possible competition between speech and other tasks).

Workload was defined as "the amount of activity a person is required to perform per unit time." Fifteen participants (eleven male, four female, ages 20 to 38) with experience using speech recognition equipment took part. Participants were required to read license plates from a video recording using the International Civil Aeronautical Organization (ICAO) alphabet and digits (0 to 9). There were two panning rates used in the video: 20 and 33 plates per minute; however, the distance to and legibility of the plates was "stable" across conditions. Participants were seated in a soundproof booth and fitted with a head-mounted microphone. An experiment consisted of six (three slow and three fast), 90-second videos. The design was within subject, with the presentation order (fast/slow) counter-balanced across participants. After each video, participants completed a modified NASA-TLX subjective workload rating. Each session was recorded on DAT and analyzed off-line. Based on the analysis of the NASA-TLX, the participants felt the fast condition to be significantly more difficult than the slow. Before the DAT recordings were analyzed, out-task speech was removed. At the word-level accuracy level, there was a significant difference between the slow and fast conditions, although the difference was only five percent. There were also significant differences in the word errors in each of three error categories: substitution, deletion and insertion. The principal cause of speaker error appeared to be erroneous selection of vocabulary items in the fast environment (e.g. "dog" instead of "delta").

The second experiment explored the effects of a secondary task on speech recognition. The primary task consisted of two stages: target identification and report filling. Participants acquired a target on the screen by moving a cursor onto one of four possible shapes, then zooming in to obtain more information (e.g. colour, heading). After identifying the target, participants completed a report describing the object (shape, colour, heading). Each experimental block consisted of six trials, and each participant performed five tasks with each input device (i.e. mini-trackball, function keys, speech input). A secondary task, mental arithmetic, was presented aurally at two levels of workload, the level of workload being determined by the need for carry-over in the calculation. The arithmetic task was recorded on DAT and played to participants during the trial. The rate of presentation was approximately 1 every 5 seconds; time and accuracy data were recorded and analyzed using a three-way ANOVA. Comparison of overall performance revealed significant main effects of performance

time between input devices. Speech input was significantly slower than other devices for target selection and report filling. Mini-trackball was faster than the function keys for target selection. A significant effect of workload was observed between the "no-workload" and each of the workload conditions; however, no significant effect was observed between the two workload conditions. Performance on the arithmetic task improved with practice (significant @ $(F(1, 214)=7.46, p<0.01))$, but this effect levelled off after the second presentation. Participants rated the workload conditions as more demanding than the no-workload conditions through paired comparisons. Recognition accuracy at the various work levels was only significantly different between the no-workload and the high workload conditions. The authors concluded that workload impacts the production of consistent speech, which leads to reduced accuracy. As well, the problem is exacerbated by the additional effect on human performance, e.g. use of illegal vocabulary.

C.7 INTERFACE DESIGN

C.7.1 The Design of User Interfaces for Digital Speech Recognition Software [Reference 14]

This project was undertaken to develop a speech interface tool for users running Unix on Alpha workstations. The following features were identified as the most desirable in a command/control speech recognition product: intuitive, speaker-independent, speaker-adaptive, continuous (vice isolated) speech, minimum use of screen area, control over interface configuration, integration with X-Windows, support for vi, emacs, and "out of the box" applications. The main interface component, "Speech Manager," provide visual feedback to users and tracks the window currently in focus. The following information is provided:

- a. **microphone status (and control)** - On/Off;
- b. **volume meter** - presents real-time feedback to the magnitude of the audio signal being "heard" by the system;
- c. **vocabulary** - two windows provide the "Always Active" and Current vocabularies; and
- d. **status** - mode (command and control or sleeping); context (active application); and history (phrase last heard by the recognizer).

The user is also provided with a Vocabulary Manager, which allows him to customize the vocabulary for any application, and a Training Manager, which allows him to train the system on newly added vocabulary. The Speech Manager Status window looks like a promising model for the feedback system in the Griffon (assuming the use of visual feedback). Because of the error-prone nature of speech recognition, the developers of Digital Speech Recognition Software (DSRS) added confirmation dialogs to critical actions to prevent catastrophic loss of data. The remainder of the paper deals with issues specific to desktop computer implementations of speech recognition, which are not related to the use of DVI in this project.

C.7.2 User Interfaces for Voice Applications [Reference 15]

"This paper discusses some of the aspects of task requirements, user expectations, and technological capabilities that influence the design of a voice interface and then identifies several components of user interfaces that are particularly critical in successful voice applications."²

The paper is a general discussion of features that are part of an effective voice interface. The most important features seem to be:

- a. to provide alternate modalities for input (i.e. speech and keyboard, let the operator choose);
- b. to provide feedback (i.e. what the recognizer heard);
- c. to allow easy error correction and recovery; and
- d. to provide clear, concise instructions.

The paper is a good overview of features to consider when developing a voice interface, but there are no startling recommendations.

C.7.3 Designing SpeechActs: Issues in Speech User Interfaces [Reference 16]

SpeechActs is an experimental conversational speech system that allows users to control basic computer applications (e-mail, calendar, stock quotations, weather forecasts) over the telephone. The initial SpeechActs system was developed based on the results of surveys and field studies. The usability testing followed Nielsen's formative evaluation philosophy, which led to changes and re-tests of the interface as soon as problems were identified. Fourteen participants were selected from the target population of "travelling professionals." Two of the fourteen participants in the study were used as pilot subjects. The results of the pilot subjects led to a redesign of the study and software bug fixes. The remaining twelve participants were divided into four groups of three, each consisting of two males and one female. An additional group of three consisted of members of the software development team and was used as a control group to evaluate the performance of the speech recognizer, removing the interface as a confounding factor. Each participant was seated at a table with a telephone and asked to complete 22 tasks. The time to complete all tasks was approximately 20 minutes. The only explicit direction given to the participants was to "answer all new messages that require a response". The tasks to be performed were embedded in the e-mail messages. Participants were provided with a "quick reference" card with sample commands to use as a memory aid. The major complaints with the system, especially for the first iteration of the design, were:

- a. slow pace of interaction;
- b. too much feedback; and
- c. users wanted to be able to interrupt the speech output.

² from the abstract

One of the research hypotheses was that certain types of interface design might increase users' success with the recognizer. None of the redesigns in this study seemed to have an impact on recognition rates. One interesting result was the lack of correlation between recognition rates and user satisfaction; some participants with the highest error rates were those who gave the most positive reviews of the system during the follow-up interview. Four challenges and their characteristics were identified by the researchers:

- a. simulating conversation - prosody, pacing, discourse pop (how to cue the user after a sub-dialog closes);
- b. transforming Graphical User Interfaces (GUIs) into Software User Interface s (SUIs) - vocabulary, information organization, information flow;
- c. recognition errors - rejection, substitution, insertion; and
- d. nature of speech - lack of visual feedback, speed and persistence, ambiguous silence.

C.8 SYNTAX/GRAMMAR

C.8.1 Development of a Direct Voice Input Syntax based on Layered Protocol Theory [Reference 1]

This paper summarizes the development of the DVI syntax used in DCIEM's Aircraft Crewstation Demonstrator (ACD) study. It includes a brief description of Layered Protocol Theory (LPT) and the LPT design methodology. DCIEM's syntax is listed and compared to the syntax from Swail and Kobierski (1997) [Reference 3].

C.8.2 A Human-Machine Interaction Analysis using Layered Protocol Theory [Reference 17]

The paper introduces Perceptual Control Theory (PCT) and LPT. Also discussed is LPTool, a software package (for the Macintosh) that allows you to document the interaction model. A simplified version of the Control and Display Unit (CDU)-Pilot interaction model is presented.

C.8.3 Using Natural Language Conventions in the User Interface Design of Automatic Speech Recognition Systems [Reference 18]

This paper presents the results of four experiments evaluating Automatic Speech Recognition (ASR) using natural language in (telephone) operator services. Two new (1995) capabilities employed in this study are "word spotting," where the ASR system recognizes key words in the dialogue, and "barge in," where users can "interrupt" the voice prompt. The authors attempted to use natural language characteristics, e.g. open-ended questions, to encourage user acceptance and yet still achieve acceptable recognition rates and transaction times. The four experiments examined various prompting strategies and also attempted to optimize the pause

between a question and the prompts so as to encourage "barge in" by expert users. Prompting users with questions decreased transaction times but increased the range of user responses and extraneous speech. Introducing a pause between the question and prompts encouraged expert users to "barge in." The natural language approach used in this study resulted in faster transaction times and better-liked systems. Although the pause between the question and prompts did encourage "barge in," other cues such as intonation, context and loudness may also be used to indicate appropriate interruption points.

C.8.4 The Prototyping of an Intelligent Agent Through Wizard of Oz [Reference 19]

Using a "Wizard of Oz" approach, the researchers examined the interaction, particularly speech input, between an intelligent agent and computer users. Participants were to teach an intelligent agent using speech input and demonstration of technique, e.g. cut and paste, bold, etc., how to format text. Of particular interest was how participants translated cultural concepts such as last name to syntactic search patterns (capitalized word after Mr. or Ms.). Although the intelligent agent, referred to as Turvy, was implemented using a Wizard of Oz technique, a formal model of the agent's learning abilities, grammar for tasks, etc. was developed, to ensure the Wizard acted consistently. Users were shown before and after examples of the data: no information regarding the syntactic features Turvy would learn was provided. The users sat at a Mac computer and worked on bibliographic entries using a mouse. For each task, the facilitator opened a document containing the data and then presented a picture of the reformatted results. The user practised on several entries until he/she could perform the task correctly. At that point, the facilitator asked the user to "teach" Turvy to perform the task. To reinforce the fantasy, the Wizard spoke in clipped sentences with a mechanical intonation. Users learnt to describe things like title and surnames in terms of their syntax, but few users could describe in the post-experiment interview the terminology it understood (they could give examples). Users tended to adopt "Turvy talk" – turning Turvy's questions into commands, which was a central hypothesis of the experimenters.

C.9 LABORATORY STUDIES

C.9.1 The Use of Word, Phrase, and Intent Accuracy as Measures of Connected Speech Recognition Performance [Reference 20]

This paper examines three measures of speech recognition performance: word, phrase and intent accuracy. Word and phrase accuracy are commonly used measures of speech recognition accuracy; intent accuracy, however, has not been used because to date (1994) most systems did not have the ability to allow users to complete tasks in multiple ways. If multiple paths to completing a task can be accurately recognized, a natural-language interface might be developed successfully. Eleven participants, male and female (although gender effects were not examined), took part in this laboratory based study. A 49-word vocabulary was used to create 392 stimulus phrases to be spoken by the participants.

The phrases were divided into three categories:

- a. complex – longer than five words [196];
- b. simple no alternate – five words or less, with no other phrase in the vocabulary which would accomplish the same goal [49]; and
- c. simple alternate – five words or less, with at least one other phrase in the vocabulary which accomplished the same goal [147].

The recognition system was an ITT-1290 speech recognition board in a Gateway 2000 4DX2-50V computer. A Plantronics SNC1657-01 microphone was used for speech input. Participants trained the speech recognition system for approximately half an hour, took a brief break, and then completed the first session of data collection. The second session was held approximately ten days later, and participants used the same voice template file from the first session, i.e. the recognition system was not re-trained. The within-subject experimental design combined three phrases types (complex, simple alternate, simple no alternate) with two sessions (1 and 2). Intent accuracy was only calculated (and relevant) for simple alternate phrases. There were no significant differences between sessions. Word accuracy was significantly better for the complex phrases than simple phrases; simple no-alternate phrases had significantly better recognition than simple alternate phrases. At the phrase accuracy level, simple no alternate phrases were more accurately recognized than complex phrases ($F(1,10)=11.12$, $p<0.008$) or simple alternate phrases ($F(1,10)=34.18$, $p<0.000$). Finally, at the intent level, both simple alternate and simple no alternate phrases were recognized more accurately than complex phrases ($F(1,10)=12.13$, $p<0.006$) and ($F(1,10)=11.12$, $p<0.008$) respectively.

C.10 RECOGNITION ACCURACY

C.10.1 Enhancing Automatic Speech Recognition with and Ultrasonic Lip Motion Detector [Reference 21]

To improve the accuracy of speech recognition systems, particularly in noisy environments, several researchers have attempted to supplement the audio information with visual data, i.e. through lip-reading. Previous attempts to include lip-reading in speech recognition systems have used video images of the mouth but because of the high processing cost (i.e. video images produce approximately 5 Mb of data per second) the practicality of such systems is questionable. This paper explored the use of ultrasonic lip-reading as a practical alternative to video (ultrasonic "imaging" produces 400 bytes of data per second). The ultrasonic image was produced through a piezoelectric material mounted on the boom microphone and oscillated at 40 KHz. As the user spoke, the movements of his mouth changed the standing wave pattern, changing the magnitude of the received signal. The acoustic signal was sampled and sent through a dynamic time warping based classifier. The ultrasonic data was down-sampled to 200 Hz, to coincide with the analysis of the acoustic data, and processed through a dynamic time warping based classifier. The classifiers for both data sets are based on dynamic time warping distances between the test utterances and the training database. The experimental task was a speaker-dependent, isolated digit recognition task. A maximum of four templates per class were used on 100 test utterances. For the speech recognizer alone, the recognition accuracy increased as the number of templates increased; however, the addition of

"extra" templates increases the computations required for classification. Recognition rates varied from 30% (at -5 dB Signal:Noise with one template) to 100% (at 10dB Signal:Noise with four templates or 15 dB Signal:Noise with one template). The automatic lip-reader had recognition rates ranging from 75.2% to 89.2%, depending on the number of templates used. Perhaps the more important observation was the sensitivity of the system to position (average cross session accuracy was 12.6%). Combining the acoustic and ultrasonic data resulted in accuracy that was at least equal to, if not better than, the individual classifiers. The best improvement was observed at 0 dB, where the combined accuracy was 93%, compared to 78% for the speech recognizer and 69% for the ultrasonic mike. There were no details provided concerning the number of participants or speech recognizer used.

ANNEX D
COMPOSITE MISSION SCENARIO

ANNEX D – COMPOSITE MISSION SCENARIO

D.1 SITUATION

The events described in this scenario take place in Eastern Europe. It is early summer in the year 2003 and a war has broken out between the Fantasians and the Union of European Countries. The Union of European Countries has requested the assistance of the North Atlantic Treaty Organization (NATO) to stop the advance of the Fantasian forces who claim that two of the countries in the European Union belong to Fantasia. NATO has agreed to assist.

The Fantasian force has been preparing to go to war with the Union of European Countries for a number of years. The Fantasians are a highly skilled and well-equipped force known for their highly integrated air defence systems.

Canada has joined the allied forces in the fight against the Fantasians. Canada has deployed three squadrons of helicopters to perform the roles of combat support and reconnaissance.

The latest intelligence report on the Fantasians indicates that front line troops are equipped with shoulder-fired Surface-to-Air Missiles (SAMs). The mechanized units supporting the front line troops are equipped with self-propelled InfraRed (IR) type SAMs for low-level air defence and anti-tank guided weapons to counter Allied armour resistance. The air-to-air threat from attack helicopters has been minimal. To date, the enemy has not been using their attack helicopters on the front line, nor have the Division Level enemy radar air defence systems been used against helicopters.

D.2 MISSION

The time is 2100 hours, 29 Jun 03, and Wolf 18 has just received a tasking for a Forward Air Control (FAC) mission. The squadron has been supporting the high intensity conflict that developed at Bridge 53 and it came as a surprise to be tasked to another sector. The crew is to depart the squadron location at 0200 hours, proceed approximately 35 kilometres (kms) south, then penetrate the Forward Edge of the Battle Area (FEBA) to an observation location where the crew will direct the air attack on an enemy stronghold. Following the FAC mission, Wolf 18 is to proceed to the Forward Ammunition and Replenishment Point (FARP) at Paulsville and conduct a hot turn around with another crew. This aircraft will become Blue Two, the second in a two-plane formation that has been tasked with inserting a 12-troop patrol into a Landing Zone (LZ) 25 kms into enemy territory near the village of Stuga. Stuga has been identified by intelligence sources as a critical communications point for the advancement of enemy troops into the northern sectors of the Union of European Countries. The patrol will be extracted covertly 48 hours after a successful insertion. The Land Forces Commander has stressed the importance of this mission and the need to remain completely covert throughout all phases of the operation.

The Mission Commander (MC) is advised that there should be good VFR weather throughout the mission. There is a broken cloud layer at 10,000 feet (ft) and the moon is in the

first quarter providing adequate illumination for NVG operations. The winds are out of the northwest at 15 knots (kts), which will make the ride a little rougher in the hilly terrain.

The MC arranges for a crew briefing with the intelligence officer. The intelligence reports for this area are sparse due to limited activity in the zone. There is apparently minimal Enemy Air Defence coverage in the area. The main threat to aircraft is Division Level SAMs and air defence guns that are widely dispersed throughout the area. The hilly terrain should make it easy to penetrate Air Defences without detection. There have been reports of troop movement through the area with some large mechanized convoys transiting to support fighting in the southern sectors.

After the briefing, the MC of Wolf 18 holds back his crew to brief the FAC mission that they will be conducting. The First Officer (FO) has already downloaded the latest maps and overlays onto the Digital Navigation Map Display (DNMD). The plan is reviewed in detail with the entire crew. The aircraft is configured with the Electro-Optical Reconnaissance, Surveillance and Target Acquisition (ERSTA) mission kit. The FO checks the latest Airspace Control Orders (ACOs) and Communications - Electronics Operating Instructions (CEOIs) for last minute changes while the Flight Engineer (FE) proceeds to the flight line to prepare the aircraft.

D.3 SCENARIO

D.3.1 Departure

It is 0130 hours. The crew of Wolf 18 have just completed all the systems checks and are ready to depart on the mission. The cloud layer has thickened and is now overcast reducing the ambient light for the NVGs. The MC turns on the IR searchlight for the departure from the squadron location. The FO lifts the aircraft into a hover and confirms the required torque does not exceed the 11,900 pounds (lbs) All-Up-Weight (AUW) torque calculated by the FE. There is limited fuel available at the FARP and with the ERSTA kit installed the helicopter weighs close to the allowable AUW. The FO remarks that the power margin for take-off will be limited, therefore he will conduct a normal departure into wind using the IR searchlight for illumination instead of carrying out an altitude-over-airspeed take-off procedure. The MC agrees and provides the FO an initial heading for the mission. Wolf 18 has been assigned a corridor to the Release Point (RP) using a contour flight profile at 250' Above Ground Level (AGL). The FO starts the climb out as the MC calls over the radio, "Zero, this is Wolf 18 departing, switching to corridor frequency." The MC selects the new frequency on Radio One, confirms the radio is set to secure mode, and checks in with the corridor controlling agency, "Corridor control, this is Wolf 18, departing HOMEPLATE en route ACP 57, over." Corridor control clears Wolf 18 into the designated corridor. The FO settles into a 250 ft AGL profile at 110 kts and proceeds en route.

D.3.2 En Route

En route to Air Control Point (ACP) 57, the MC busies himself with a route study using the DNMD. The FO calls for a cockpit check from the back, which prompts the FE to move forward, and check the aircraft gauges. The FE reports, "Cockpit check complete with

2010 lbs fuel remaining, cabin area secure." The MC crosschecks the status of the Navigation (Nav) system to ensure that the Long Range Navigation (LRN) system is operating correctly. The Global Positioning System (GPS) has a Figure of Merit of two and the system is set to Doppler Revert mode. The MC crosschecks the map to determine the departure heading from the RP. To confirm the track, the MC calls up the calculator page on the CDU for Bearing and Range and enters the RP and Observation Point (OP) information. The MC depresses the Start Time soft key to enter the current time, then the Estimated Time of Arrival (ETA) soft key and observes the result. The MC switches to the Present POSition (PPOS) page and determines from the CDU header that they are ten minutes back from the RP.

At two minutes back from the RP, the MC calls up the calculator page for ETA. He enters a ground speed of 60 kts, the planned average speed during the Nap-Of-the-Earth (NOE) profile to the OP. He uses the Flight Planned Route mode and the current Zulu time for the calculation. The calculation gives an ETA of 0305 Zulu which correlates with the plan. He advises the remainder of the crew over the intercom, "We're two minutes back from the RP."

D.3.3 Release Point to Observation Point

At 0235, Wolf 18 reaches the RP and the Nav system automatically switches to the next waypoint. The MC tells the FO to turn to a heading of 273 degrees as he begins a 5T check. The check comprises:

- a. **Time.** The MC checks that he has started the elapsed time clock passing over the waypoint.
- b. **Turn.** The MC confirms the planned heading and that the aircraft is turning to adopt the new heading.
- c. **Track.** The MC confirms through outside references that the aircraft is heading in the right direction according to the route he has marked on the map, that the Avionics Management System (AMS) is pointing with needle number one to the correct waypoint, and that the Nav header information on the CDU is correct.
- d. **Throttles.** The MC completes, or requests that the FE complete, a full cockpit check.
- e. **Talk.** The MC the passes a position report via the radio. The MC selects the Comm Summary page on the FO's CDU and confirms that Radio Two is set to HaVe QuicK (HVQK) anti-jamming mode. He then selects Radio Two on the rotary selector and initiates the radio call:

"Zero, this is Wolf 18, over."

"Wolf 18, this is Zero, over."

"Wolf 18 is one minute back from ACP 57, ETA for OP is 0305, over."

"Zero, roger, out."

The MC confirms that Pointer #1 is pointing in the right direction and that the Nav Header agrees with the Track Angle and Departure Check results. The Doppler Nav system is placed in Silent Mode to reduce emissions, the Identification Friend-or-Foe (IFF) is turned off and all the aircraft lighting is confirmed off. The MC uses the DNMD to guide the FO along the low ground en route to the OP 25 kms ahead. The hilly terrain provides excellent cover, but with the low ambient light conditions it proves difficult for the FO to remain clear of obstacles. The ERSTA Operator advises that he has a limited viewing area at the lower altitude. The FO pulls up to 100 ft AGL in some areas due to the poor terrain reference.

Ten kms back from the OP, the MC scrutinizes the map features in the vicinity of the OP. The MC analyzes the contours on the map to confirm the approach and departure paths to the OP. The FE visually checks the cabin, and then returns to a visual search out the window for signs of the enemy. The visibility has improved and the FO can see the treetops along the bottom of the valley. The flight profile is adjusted to 50 ft AGL at 80 kts. The uniform layer of trees is beginning to give way to cultivated fields and the terrain is beginning to flatten. The MC continues to provide directions to the FO using the DNMD and indicates to the FO that it is time to slow down and proceed NOE. The FO slows to 40 kts and moves down to 25' to 30' AGL following along the sides of the farmers' fields at the edge of the treeline. The FO, ERSTA Operator, and the FE are scanning for signs of poles that may indicate wires, as well as searching for any signs of the enemy.

At 0302, the MC calls out, "One minute back, do you have two full?" The FO replies, "Roger, one minute back, I have two full, slowing." The MC confirms all the systems are functioning within limits and requests from the FE, "The cockpit check is complete, cabin area?" The FE calls, "Cabin area secure, ready for the hover, call for the door." The MC and ERSTA Operator positively identify the location of the OP a half km ahead and the MC describes the area to the FO. "Roger, I have the area at two o'clock, turning right for the area, FE clear for the door". The FE replies "Roger, right door coming open, I have the area."

The aircraft is brought into the hover behind a treeline that is on the front face of a high ridge. The enemy target for the FAC mission is located in the valley approximately six kms from their location. The OP should provide excellent cover for the aircraft, as the treeline is uneven and the backdrop of the ridge will keep them in the shadows. The aircraft is brought into a hover and the crew prepares to unmask.

D.3.4 Forward Air Control

The MC contacts Joint Surveillance Target Acquisition Radar System (JSTARS) and receives the information about the air sortie. The ERSTA Operator reviews the tactical display and confirms that the MC has the Initial Point (IP) information available from the DNMD. After quickly reviewing the initial plan among the crew, the MC directs the aircraft forward to another OP. The aircraft is repositioned three kms from the target to provide the ERSTA Operator a better laser line. The ERSTA Operator conducts another sweep of the area with the Thermal Imager (TI) and confirms that there is no vehicle movement or people in the area. Contact is made with the fighter aircraft who provides the mission details as per Standard Operating Procedures (SOPs). The ERSTA Operator confirms that the correct codes are in use and prepares the mission brief for the FAC aircraft. The MC is satisfied that the control procedures

have been followed and authorizes the mission. The ERSTA Operator establishes a datalink with the fighter and sends the 9-line FAC briefing. The ERSTA operator requests that the MC arm the laser designator. The MC identifies the arming switch and places it in the armed position.

The fighter aircraft calls by the IP. A moment later the fighter enters an orbit pattern at high altitude and advises "in the wheel." This is the indication for the ERSTA Operator to illuminate the target for initial identification by the fighter. The FO unmask the aircraft; the ERSTA Operator confirms positive target identification through the TI and uses the laser designator to illuminate the target; simultaneously, the ERSTA Operator takes and stores imagery of the target. Shortly thereafter the pilot in the fighter calls, "I have the target" and the ERSTA Operator ceases target illumination.

The fighter pilot manoeuvres the aircraft into position for weapon delivery and calls, "Tipping in" followed a few seconds later by, "Wings level." The ERSTA Operator focuses attention on the TI image. The fighter pilot releases the weapon and calls "sparkle." The ERSTA Operator illuminates the target with the laser, acknowledges the radio call from the fighter and waits.

The weapon strikes a direct hit momentarily washing out the image in the TI. The ERSTA Operator releases the trigger, stopping the laser designation and scans the area for troop or vehicle movement with the TI. After the scan is complete, the ERSTA Operator trains the TI onto the area of the attack to assess the damage. The video recorder was running throughout the mission, but the ERSTA operator captures a number of images of the target for the Battle Damage Assessment (BDA). Satisfied that the damage assessment is complete, the ERSTA Operator advises the MC who directs the aircraft to withdraw. The ERSTA Operator composes a BDA message and transmits it to JSTARS via the datalink.

D.3.5 Refuel and Reconfigure

The MC navigates and provides direction to the FO as they depart the FAC mission and head for the planned FARP. Just prior to crossing the FEBA the MC selects the IFF page on the CDU and turns the IFF on. Switching to the Doppler page the MC presses the soft key to set the Doppler Mode to NAV. After a brief transit the MC identifies the FARP and the FO confirms he has the landing area. The FO manoeuvres the helicopter to land in the designated area and once safely on the ground, the ERSTA Operator completes the shutdown checks. The FE and ERSTA Operator proceed to disconnect the part of the mission kit installed in the cabin area and remove it from the aircraft. Meanwhile, a new crew approaches the aircraft to relieve the crew of Wolf 18. Once the aircraft is reconfigured and the crew has completed the required checklist procedures, they proceed to the refuelling point and conduct Hot Closed Circuit Refuelling (HCCR).

D.3.6 Observation Point to Pick-Up Zone

The Aircraft Captain (AC) does not have the benefit of using a DNMD and refers to the map to determine the heading and range to the Paulsville Pick-Up Zone (PZ). The lead aircraft is already en route and they will join them at the PZ. The MC inserts the new data

cartridge into the Data Transfer Unit (DTU), selects the INI page on the CDU, and presses the DTS LOAD soft key. Once the load is confirmed complete the AC selects the Flight Planning page, calls up the flight plan, then activates it. He confirms the heading and distance to the Paulsville PZ agree with what is determined from the map. He communicates this information to the FO, who then lifts off into a hover and turns the aircraft towards the direction of Pointer #1 on the Horizontal Situation Indicator (HSI). Prior to initiating a transition to forward flight, the FO calls for a cockpit check at which time that AC asks the FE to come forward and complete the check. The FE moves forward quickly and confirms that all of the aircraft temperatures and pressures are in the acceptable ranges, as well as checking the cabin area for security. Once the check is complete, he calls "cabin area secure, clear right and behind for departure." The FO initiates the transition and climbs to the planned cruise profile.

The AC checks his log card and determines that the next frequency required is 49.8 FM. On the Comm Summary page he sets up the CDU for radio number two, then enters the frequency. He then pushes the settings button in order to confirm that the radio has been set to FM. The AC changes the CDU to the Nav Header in order to determine the ETA to Paulsville. He then uses his rotary selector to select radio No. 2 for transmission. As the helicopter departs the FARP, the AC initiates a radio call:

"49 Alpha this is Wolf 23, over."
"Wolf 23 this is 49 Alpha, over."
"Wolf 23, ETA Paulsville 0411 over."
"49 Alpha, out."

The AC notes the time and prepares to change the IFF mode one setting. Referring to his log card to determine this required code, the AC uses the CDU to preset the squawk code, so that at 0400, he needs only press the enter button and the code will be entered into the IFF. The AC then returns to the task of navigation. He confirms the present location of the aircraft on the map, as well as a new heading for the FO to steer in order to go around an upcoming ridge. The FO is now flying at 100 AGL at 100 kts. The FE searches visually for any enemy activity in the area.

D.3.7 Troop Pick-Up

At 0400 the AC presses the enter key to change the IFF code. Prior to entering the Restricted Operating Zone (ROZ) around Paulsville, the MC contacts 49 Alpha. 49 Alpha confirms that the zone is clear of air traffic and that Wolf 23 can proceed directly to the PZ. The FO refers to Pointer #1 on the HSI that is pointing directly at the Paulsville airstrip. The AC provides minor-heading corrections based upon the route information on the map. Wolf 23 enters the ROZ. The AC checks the wind readout on the CDU Nav Header in order to determine the best direction for landing. He communicates this information to the FO who acknowledges the heading and informs the crew that they will conduct a straight-in approach to the airstrip. Looking at the ETA displayed on the CDU, the MC determines that they are now two minutes back from landing. The FO calls for a cockpit check. The FE moves up from the back in order to determine that all the temperatures and pressures are within limits. He then moves back into the cabin and confirms that the cabin area is secure and calls, "Cockpit check complete, cabin area secure, call for the door." When on final approach approximately 30 seconds back from

landing, the FO decelerates. As the speed decreases through 80 kts, the FO calls, "Through 80, clear for the door." The FE opens the right door and calls, "Right door coming open." Upon seeing the area the FE calls, "I have the area, you're clear right and below." The AC identifies the other helicopter, Blue Lead, at the far end of the airstrip and directs the FO to taxi over to the other aircraft once he has landed. The FO continues the approach to the middle of the airstrip where he arrives at a four-foot hover into wind. He then taxis down the airstrip to where the other aircraft is running on the ground and moves into position leaving a rotor and a half clearance. Once on the ground, the FO rolls the throttles to idle and switches the force trim on. The AC then tells the rest of the crew that he is disembarking the aircraft in order to meet the liaison officer who he can see walking toward them.

The FE starts to prepare the cabin area for the troops to be transported. He arranges all the seat belts and opens the door on both sides of the aircraft. He then scans the side of the airfield with his NVGs to locate the troops. He notices a group of soldiers with rucksacks moving towards the area where they are now. After confirming with the FO that it is clear to proceed he pulls out a flashlight from his pocket and signals to the troops to come towards the aircraft. The FE meets the soldiers outside of the rotor path and queries the lead soldier as to whether they have everything with them. The leader replies that they have all their equipment and that they are ready to go. The FE receives an indication from the FO that it is clear to proceed, then begins to load the troops. He places all the rucksacks on the forward part of the cabin area and then use the cargo strap secure them. The troops then enter the cabin of the aircraft, occupy a seat, and fasten their seat belts. By this time the AC is returning to the aircraft. He straps in and plugs in to the intercom system. He has received some new information on contacts and on the route. He has already marked the map and briefs the FO on the minor changes. Their departure time will be in four minutes.

D.3.8 Air Mobile Departure

Two minutes prior to departure, the FO has increased the aircraft throttles to full and has completed the pre-take-off check. The AC has selected radio number one and is setting the radio to HVQK channel 01. The AC then checks in with Blue Lead to ensure that the radio is functioning correctly in HVQK.

The AC folds his map and prepares for departure. He confirms that the flight plan has been activated and that the next waypoint on the route corresponds to his map. The IFF page is selected and the IFF is set to "Off" for the formation flight. He confirms on the Nav Header that the range and bearing to the waypoint agree with the route marked on the map. He then ensures that that FO has his long-range Nav source set on his HSI and quickly checks to see if the FO's Pointer #1 is pointing in the right direction. The AC advises the crew that the lead aircraft will be departing to the left with an initial heading of 085 to the first waypoint and that his Pointer #1 is indicating the correct direction to the first waypoint. Blue Lead begins to lift-off, at which time the FO of Blue Two begins to lift up the aircraft into a low hover. Blue Lead initiates a slight pedal turn to the left and begins to depart on the initial heading of 085. The FO of Blue Two follows behind Blue Lead staying off to the right hand side of the lead aircraft to avoid the rotor wash. The first leg will be flown at 200 ft AGL in the corridor that was briefed in the initial briefing.

Once the aircraft is through translational lift, the AC refers to his map and completes the departure checks.

D.3.9 Air Mobile En Route

Blue Lead leads the formation out of the ROZ and into the low terrain leading towards Stuga. The FO scans the terrain on both sides of Blue Lead looking for the best low ground to use and looking for any obstacles in the flight path. The FO is maintaining eight to ten rotors clearance from the lead aircraft and moves laterally in Free Cruise formation to optimize the low ground.

The AC follows along on the map to ensure that the correct route is followed. The AC continually uses the CDU to compare the ETA to the LZ the information on his log card.

D.3.10 Air Mobile Detection by ZSU 23-4

The flight-planned route for the formation includes a six-km leg paralleling a highway prior to turning back into the hilly terrain on the west of Stuga. As the Wolf Blue formation turns toward the highway following the descending terrain, the lead aircraft suddenly turns left and takes a small re-entrant back into the hills. Blue Two's Radar Warning Receiver (RWR) synthetic voice suddenly announces, "ZSU, ZSU, 12 O'clock, Searching!" Blue Two now understands why the lead aircraft suddenly broke formation and took the low ground back into the hills. The AC directs the FO to take the next piece of low ground on the left as they have already flown past the re-entrant that Blue Lead took. The RWR ZSU symbol fades on the RWR display as the FO manoeuvres the helicopter back into the hills.

The formation is now separated. Standard Operating Procedures dictate that the formation should rejoin at the LZ near Stuga. Because the formation has separated, Blue Two is now responsible for navigation to the LZ and the AC uses both the map and PPOS page on the CDU to determine the exact position of the helicopter. He pulls up the PPOS page on the CDU, which gives his current position in UTM grid that he can easily find on the map. He then crosschecks the CDU flight plan to ensure that the LRN pointer is accurate. The AC quickly does a terrain assessment and determines a new route to the LZ that will avoid the area of the highway. He verbally directs the FO to turn left to a heading of 110 degrees and then follow the Nav pointer on the HSI. The AC quickly calculates a new ETA at the LZ and determines they will be approximately four minutes late. The FO advises the AC that they should turn their IFF on because they are no longer in formation. The AC selects the IFF page and activates the system.

The AC of Blue Two has been monitoring the radios and does not hear Blue Lead send a contact report on the ZSU 23-4. He decides to send one himself and confirms that the Radio 2 frequency is set to Hawkeye, the Airborne Warning And Control System (AWACS) aircraft patrolling the surrounding area. The AC establishes contact with Hawkeye using HVQK on Radio 2 and sends the contact report.

D.3.11 Arrival at Drop Zone

The AC looks down at the Nav Header on the CDU and determines that they are 2 minutes back from the LZ. He calls over the intercom to inform the crew, so that the FO can prepare for the tactical approach to the area and the FE can advise the troops. The AC looks at the Nav Header and provides the wind indication to FO. The winds are 90 degrees off to the right side of the aircraft so the FO plans a right turn into wind just prior to the LZ. The AC describes some terminal navigation features off of the map that the FO can use to identify the area and assist in lining up into wind for final. The AC calls over the intercom to keep a lookout for Blue Lead who should be in the vicinity of the LZ. At one-minute back from landing, the FO begins to reduce speed and starts a gradual right turn to line up into wind. The AC calls, "One minute back". The FE passes the timing information to the section commander, who in turn signals his troops to prepare for landing.

Making the final turn into the area, the FO sees Blue Lead directly over the LZ. The AC of Blue Two selects radio number 1 and transmits to Blue Two, "Blue Lead, this is Blue Two, coming up on your right side." Blue Lead clicks the radio transmit button twice acknowledging the transmission.

D.3.12 Troop Insertion

The AC puts the map away and calls for a cockpit check. The AC completes the check and isolates the FO's radios to InterCommunications System (ICS). The FE isolates his radios to ICS and calls the cabin area secure for landing. The FO calls decelerating below 80 kts on final approach to the area, at which time the FE opens the right door and begins to direct the aircraft into the area.

The ground is not suitable for landing so the FO brings the helicopter into a low hover and advises the FE that the troops will have to deplane from the hover. As the troops are going out, the AC is calling the hover torque at regular intervals for the FO. He is interrupted by a radio call from Blue Lead indicating "Ready for Departure" and that the route back would be via the alternate. The AC checks that he is selected to Radio 1 and transmits "Standby" to Blue Lead. The AC continues to assist the FO until all the troops are on the ground and the FE has confirmed that they are clear of the helicopter. The AC calls for a cockpit check for departure, which he completes followed by the FE calling, "Cabin area secure, clear right and behind, clear above ready to move up." The AC calls over Radio 1, "Blue Two, ready".

D.3.13 Drop Zone Departure

Blue Lead transitions into wind and, accelerating through 40 kts, turns 180 degrees to the left, following the alternate route back to Paulsville. Blue Two takes off into wind and follows Blue Lead through the left turn down into the Neripite Valley. The AC selects the IFF page and switches the IFF off now that the formation has reformed.

D.3.14 En Route Via Alternate Route

The AC of Blue Two refers to his map and crosschecks the route that Blue Lead is taking. They are on track and he communicates the navigation information to the FO. Once down in the bottom of the valley, the route takes them up a large river towards Paulsville. The riverbed should provide good cover from detection until they are back into friendly territory another 30 kms north of their present location. The transition from the high ground, where they disembarked the troops into the low ground of the river valley, is the only area where the terrain is poor for masking the helicopter. The AC tells the crew over the ICS to keep a lookout for enemy activity in the area, as they do not have much intelligence on enemy activity for the sector.

D.3.15 Engagement by SA-8

Suddenly the RWR synthetic voice announces, "Radar Searching." The AC quickly checks the RWR display and determines that it has identified radar searching from the right side of the aircraft. The FO looks intently for any gaps in the trees ahead where they can mask the aircraft. The riverbed provides the best cover and the FO changes the heading slightly to intercept the river. The FE indicates that he has visually acquired the riverbed and the FO confirms that that is where he is heading. The RWR synthetic voice announces, "SA-8, One O'clock, acquisition, tracking". The Missile Approach Warning System (MAWS) alarm suddenly goes off indicating an inbound missile. "SA-8, SA-8, Two O'clock, Launch! Missile, Missile, 2 O'clock, Launch!" the synthetic voice announces. The AC yells out, "We have a missile inbound at 2 O'clock, Take the riverbed! Take the riverbed!" The FO banks hard to the right, followed by a hard left bank down into the riverbed. The rotors barely clear the trees as the helicopter dives into the protection of the narrow river valley. The FO strains to judge altitude through the NVGs due to the dark shadows in the tight valley. He lowers the collective and starts a level deceleration while being careful to stay concealed behind the trees. The MAWS alarm turns off and the missile symbol on the RWR fades. As the signal is lost the RWR announces, "Autolock broken." The SA-8 Symbol also fades and the synthetic voice is once again quiet.

The AC calls to the FO to bring the aircraft into a hover at the next available spot where there is good cover. The FO is hover-taxiing NOE at 30 kts and finds a good bend in the river surrounded by tall trees. The FO stops the aircraft in a hover with the rest of the crew calling obstacle clearances. Once established in the hover, the AC looks at the map in an attempt to determine from where the missile was launched and how they can safely depart the area without exposing their location again. The AC reminds the crew to keep their heads out and call any contacts.

The AC looks at the map and determines which heading to fly to get back on the alternate route back to Paulsville. He re-activates the flight plan on the CDU and cycles through the successive waypoints to get on the right leg of the route. The AC then calls for a cockpit check for departure and describes the turnout back to the route, as well as the type of terrain that will encountered. The FE completes the check and calls the cabin area secure.

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The FO takes off into wind and conducts a left turn through 40 kts that will take them back to track. The AC continues to call navigation information and crosschecks the AMS to ensure they are on their route. Contacting Blue Lead, the AC determines that both aircraft are safe. Blue Lead provides an update on their position and a location to rendezvous along the route home.

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ANNEX E
DVI OPERATOR INTERFACE SPECIFICATION

31 Aug 00

ANNEX E – DVI OPERATOR INTERFACE SPECIFICATION**E.1 GENERAL**

The Operator Interface (OI) Specification described in Annex E is limited to a Direct Voice Input (DVI) system suitable for a usability trial in a prototyping facility. Refinements to the specification will arise as further research and development is completed.

There are three components to the OI specification: syntax, feedback, and Crew Resource Management (CRM). Each element is described in detail in the following subsections.

E.2 SYNTAX LISTING

Table E-1 outlines the complete DVI syntax, as determined during the syntax development phase of the project. The words in *italics* represent variables that are replaced by numeric or text strings during usage. As an example, *V/UHF Frequency* might be replaced by "121.5" while *Waypoint* may be replaced by "Summer Hill." Numeric variables are constrained to values valid in the Control and Display Unit (CDU).

Table E-1 Direct Voice Input Syntax Listing

Action	Target	Target	Parameter
Set	Radio	1	AM
		2	FM
			<i>V/UHF Frequency</i>
			<i>Preset Number</i>
			<i>HVQK Channel Number</i>
			<i>Preset Name</i>
		3	<i>UHF Frequency</i>
			<i>Preset Number</i>
			<i>Preset Name</i>
			<i>HVQK Channel Number</i>
		5	<i>HF Frequency</i>
			<i>Preset Number</i>
			<i>Preset Name</i>
	VOR		<i>Frequency</i>
			<i>Waypoint</i>
			<i>ICAO Identifier</i>
	ILS		<i>Frequency</i>
			<i>Waypoint</i>
			<i>ICAO Identifier</i>
	HSI_Mode		ADF
			DF
			Long Range

Table E-1 Direct Voice Input Syntax Listing

Action	Target	Target	Parameter
			Short Range
			En Route
			Terminal
			Approach
			Civ
			Civil
			Tac
			Tactical
	Long Range Source		GPS
			GPS Revert
			Doppler
	DME		Normal
			Hold
			Standby
	Flight Plan Sequence		Automatic
			Auto
			Man
			Manual
	ADF		Frequency
	IFF		IFF Code
	Doppler Update		Auto
			Automatic
			Man
			Manual
	Header		Comm
			Nav
			Tactical
			Tac
			Civ
			Civil
Squawk			IFF Code
			IDENT
Activate	Flight Plan		
			Next
			Previous
	Present Position Direct		Waypoint Waypoint Number
			Waypoint Number
			Waypoint Name
	PPOS		Waypoint Waypoint Number
			Waypoint Number
			Waypoint Name

Table E-1 Direct Voice Input Syntax Listing

Action	Target	Target	Parameter
Start	Flight Plan		
			Next
			Previous
	Present Position		Waypoint Waypoint Number
	Direct		Waypoint Number
			Waypoint Name
	PPOS		Waypoint Waypoint Number
			Waypoint Number
			Waypoint Name
Switch to	Radio		1
			2
			3
			5
	ICS		
	Private		
	CDU		1
			2
Switch me to	Radio		1
			2
			3
			5
	CDU		1
			2
	ICS		
	Private		
Monitor	Radio		1
			2
			3
			5
			All
	Nav		A
			B
			None
			All
	All		Radios
			Nav
Stop Monitoring	Radio		1
			2
			3
			5
			All

Table E-1 Direct Voice Input Syntax Listing

Action	Target	Target	Parameter
	Nav		A
			B
			None
			All
	All		Radios
			Nav
Isolate me to	Radio		1
			2
			3
			5
	Nav		A
			B
	ICS		
Isolate to	Radio		1
			2
			3
			5
	Nav		A
			B
	ICS		
Isolate	Radio		1
			2
			3
			5
	Nav		A
			B
	ICS		
Display	Quick Review		Waypoints
			Storepoints
			Mobile
			Comm
			Radio
	Data		Waypoint Name
			Waypoint Waypoint Name
			Waypoint Waypoint Number
			Preset Name
			Preset Preset Name
			Preset Preset Number
			HVQK Preset Number
			Flight Plan
			Present Position
			Message

Table E-1 Direct Voice Input Syntax Listing

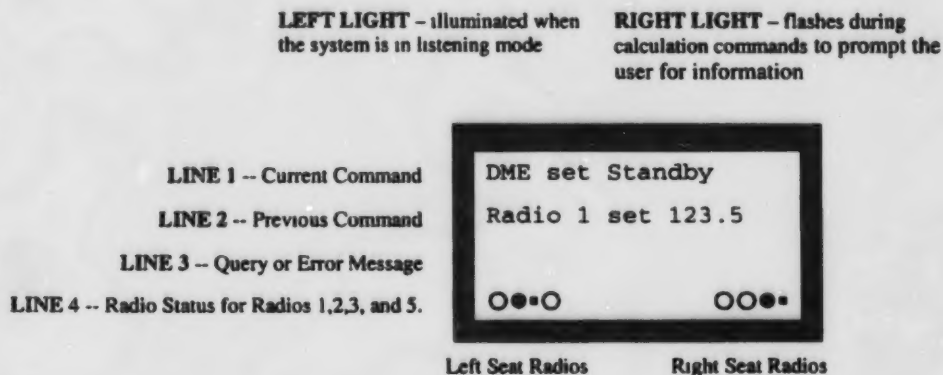
Action	Target	Target	Parameter
			IFF
			Status
			Nav
			Navaid
			Doppler
			Comm Summary
			PPOS
			GPS
		Radio	1
			2
			3
			5
	Header		Comm
			Nav
			Civil
			Civ
			Tactical
			Tac
Calculate	Endurance		<i>Fuel</i>
			<i>Fuel Flow</i>
			<i>Groundspeed</i>
	ETA		<i>From Waypoint</i>
			<i>To Waypoint</i>
			<i>Start Time</i>
			<i>Groundspeed</i>
			<i>Flight Plan / Direct</i>
	Fuel Requirements		<i>From Waypoint</i>
			<i>To Waypoint</i>
			<i>Fuel Quantity</i>
			<i>Fuel Flow</i>
			<i>Flight Plan / Direct</i>
	Bearing and Range		<i>To Waypoint</i>
			<i>From Waypoint</i>
	Duration and Range		<i>Fuel Quantity</i>
			<i>Fuel Flow</i>
			<i>Groundspeed</i>
	Required Groundspeed		<i>From Waypoint</i>
			<i>To Waypoint</i>
			<i>Start Time</i>
			<i>Time on Target</i>
			<i>Flight Plan / Direct</i>

E.3 DESCRIPTION OF THE FEEDBACK SYSTEM

A small Liquid Crystal Display (LCD) panel provides visual feedback, in the form of text, to the pilot. In addition to this panel, four distinct tones are required. They are:

- a. **Querying** – heard when the system is put into listening mode or during a calculate command when the user is being queried for information;
- b. **Success** – heard when command was recognized and completed successfully;
- c. **Error** – heard when command was recognized but there was an error during execution; and
- d. **Standby** – heard after uttering the "Standby" command and the system goes into standby mode.

A brief description of the visual feedback display is presented in Figure E-1. A sample dialog between the pilot and the DVI system, including the displayed feedback, is presented in Figure E-2.

**Radio Status Legend:**

- A "○" means Monitoring Radio
 A "●" means Radio Selected for Transmit
 A "●" is a placeholder (neither transmitting nor monitoring)

In the above example, the Left Seat Pilot is monitoring Radios 1 and 5, transmitting on Radio 2, and neither monitoring nor transmitting on Radio 3. The Right Seat Pilot is monitoring Radios 1 and 2, transmitting on Radio 3, and neither monitoring nor transmitting on Radio 5. Note that there is no indicator for Radio 4 as it is not installed on the aircraft.

Figure E-1 Visual Display of DVI Feedback System

DVI Commands Issued by the left-seat pilot:

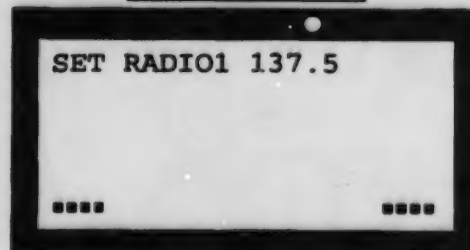
"Computer"

QUERY BEEP



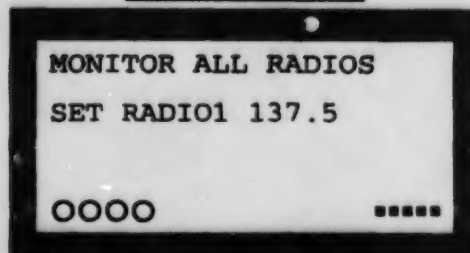
"Set Radio 1 137.5"

SUCCESS BEEP



"Monitor all radios"

SUCCESS BEEP



"Switch to Radio 5"

SUCCESS BEEP

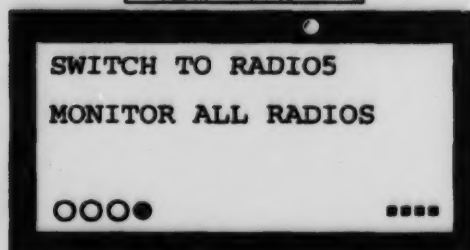


Figure E-2 Direct Voice Input Feedback Description (Page 1 of 4)

"Set Radio 1 29.5"

ERROR BEEP

SET RADIO1 29.5
SWITCH TO RADIO5
!INVALID FREQUENCY!
OOO● ●●●●

"Set Radio 1 129.5"

SUCCESS BEEP

SET RADIO1 129.5
SET RADIO1 29.5
OOO● ●●●●

"Calculate ETA"

QUERY BEEP

CALCULATE ETA
SET RADIO1 137.5
?FROM WP?
OOO● ●●●●

"Waypoint 9"

QUERY BEEP

SWITCH TO RADIO5
WP 9
?TO WAYPOINT?
OOO● ●●●●

Figure E-2 Direct Voice Input Feedback Description (Page 2 of 4)

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"Waypoint 16"

QUERY BEEP

CALCULATE ETA

WP 16

?GROUNDSPEED?

OOO●

"75 knots"

QUERY BEEP

CALCULATE ETA

GS 75

?START TIME?

OOO●

"Now"

QUERY BEEP

CALCULATE ETA

13:42:07

?FLT PLN OR DIRECT?

OOO●

"Flight Plan"

SUCCESS BEEP

CALCULATE ETA

FLT PLN

ETA 14:06:31

OOO●

Figure E-2 Direct Voice Input Feedback Description (Page 3 of 4)

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"Standby"

STANDBY BEEP

CALCULATE ETA

FLT PLN

ETA 14:06:31

OOO●

....

"Computer"

QUERY BEEP

CALCULATE ETA

FLT PLN

ETA 14:06:31

OOO●

....

"Set Long Range Source to Doppler"

SUCCESS BEEP

SET LRN SOURCE DOP

CALCULATE ETA

ETA 14:06:31

OOO●

....

"Standby"

STANDBY BEEP

SET LRN SOURCE DOP

CALCULATE ETA

ETA 14:06:31

OOO●

....

Figure E-2 Direct Voice Input Feedback Description (Page 4 of 4)

E.3 CREW RESOURCE MANAGEMENT

To take advantage of hands-free control in the cockpit, the existing CH 146 Griffon CRM was modified to redistribute tasks between the Flying Pilot (**FP**) and Non-Flying Pilot (**NFP**). The revised CRM model re-allocates two tasks to the FP. In addition to flying the aircraft, the FP is responsible for:

- a. maintaining communications with the squadron; and
- b. waypoint selection, e.g. incrementing/decrementing waypoints, initiating Present POSition (**PPOS**) direct.

The NFP performs the remainder of cockpit tasks.

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ANNEX F

DVI OPERATOR INTERFACE EVALUATION MANUAL INPUT TRIAL QUESTIONNAIRE

31 Aug 00

**ANNEX F – DVI OPERATOR INTERFACE EVALUATION MANUAL
INPUT TRIAL QUESTIONNAIRE**

**Manual Input
Participant Questionnaire**

Participant ID: _____

Date: _____

Flying Pilot or Non-Flying Pilot

Session #1 or #2

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DOC NO
1000-1209

Workload Section

Workload is the effort required to perform a task (operator load). Please rate the various mission segments of the experiment according to your perception of the demands made upon you. Rate each demand independent of your previous answers. All are rated from "Low = 0" to "High = 10". Please circle your response rating in Table F-1.

Table F-1 Workload Effort for DVI Operator Interface Evaluation Manual Input Trial Questionnaire

Name	Description	Mission Segment	Ratings from Low "0" to High "10"									
Visual Demand	Effort needed to gather all visual information required for each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9 10
		Re-tasking	0	1	2	3	4	5	6	7	8	9 10
Auditory Demand	Effort needed to gather all auditory information required for each mission segment.	Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9 10
		Transit and Recce	0	1	2	3	4	5	6	7	8	9 10
		Re-tasking	0	1	2	3	4	5	6	7	8	9 10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9 10
Mental Demand	Thinking and perceptual effort required for each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9 10
		Re-tasking	0	1	2	3	4	5	6	7	8	9 10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9 10
Physical Demand	Physical activity required for each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9 10
		Re-tasking	0	1	2	3	4	5	6	7	8	9 10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9 10
		Transit and Recce	0	1	2	3	4	5	6	7	8	9 10
		Re-tasking	0	1	2	3	4	5	6	7	8	9 10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9 10

F.2

31 Aug 00

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DOC NO
1000-1209

Table F-1 Workload Effort for DVI Operator Interface Evaluation Manual Input Trial Questionnaire

Name	Description	Mission Segment	Ratings from Low "0" to High "10"									
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9 10
Time Pressure	Degree of time pressure felt for each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9 10
		Re-tasking	0	1	2	3	4	5	6	7	8	9 10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9 10
Your Own Performance	Success at accomplishing the tasks of each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9 10
		Re-tasking	0	1	2	3	4	5	6	7	8	9 10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9 10
Effort	Overall level of effort, both physically and mentally, during each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9 10
		Re-tasking	0	1	2	3	4	5	6	7	8	9 10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9 10
Frustration	Level of frustration during each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9 10
		Re-tasking	0	1	2	3	4	5	6	7	8	9 10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9 10
Anxiety	Level of anxiety during each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9 10
		Re-tasking	0	1	2	3	4	5	6	7	8	9 10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9 10

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Table F-1 Workload Effort for DVI Operator Interface Evaluation Manual Input Trial Questionnaire

Name	Description	Mission Segment	Ratings from Low "0" to High "10"										
		Re-tasking	0	1	2	3	4	5	6	7	8	9	10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10
Global Workload	Considering all aspects, how would you rate the demands of the current mission segments.	Transit and Recce	0	1	2	3	4	5	6	7	8	9	10
		Re-tasking	0	1	2	3	4	5	6	7	8	9	10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10

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Feedback Section

Feedback refers to all information provided by the CDU, which allows you to assess or diagnose the current state of the system.

1. Using the rating scale below, rate how often during the mission you:

Rarely	Occasionally	Sometimes	Frequently	Often
1	2	3	4	5
a. looked at and/or attended to the CDU?			1	2 3 4 5
b. looked at and/or attended to the CDU soon after inputting a MI (manual input) command?			1	2 3 4 5
c. experienced visual conflicts? (e.g., you wanted to, but were unable to, look at CDU and engine/cockpit instruments at the same time)			1	2 3 4 5
d. experienced auditory conflicts? (e.g., you wanted to, but were unable to, listen to a radio transmission and monitor a crew conversation at the same time)			1	2 3 4 5

2. Using the rating scale below, rate the amount of feedback provided by the CDU. Circle your response.

Far too little feedback	Slightly too little feedback	Appropriate amount	Slightly too much feedback	Far too much feedback
1	2	3	4	5

3. Using the rating scale below, rate the CDU feedback in terms of allowing you to complete the tasks required. Circle your response.

Completely Inadequate	Very Inadequate	Somewhat Inadequate	Neutral	Somewhat Adequate	Very Adequate	Completely Adequate
1	2	3	4	5	6	7

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4. Using the rating scale below, rate the CDU feedback in terms of allowing you to trouble-shoot the system. Circle your response.

Completely Inadequate	Very Inadequate	Somewhat Inadequate	Neutral	Somewhat Adequate	Very Adequate	Completely Adequate
1	2	3	4	5	6	7

5. Using the rating scale below, rate the ease of dividing your attention between the CDU and the outside visual scene and vice versa. Circle your response.

Very Easy	Easy	Borderline	Difficult	Very Difficult
1	2	3	4	5

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6. Please list any additional comments you have about the feedback for manual input.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There is no handwriting or other markings on the paper.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There is no handwriting or other markings on the paper.

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8. Please provide any thoughts you have on the CRM in the Griffon cockpit.

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There is no handwriting or printed text on the paper.

ANNEX G
DVI OPERATOR INTERFACE EVALUATION VOICE INPUT
TRIAL QUESTIONNAIRE

31 Aug 00

**ANNEX G – DVI OPERATOR INTERFACE EVALUATION VOICE INPUT
TRIAL QUESTIONNAIRE**

DVI

Participant Questionnaire

Participant ID: _____

Date: _____

Flying Pilot or Non-Flying Pilot

Session #1 or #2

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DOC NO
1000-1209

Workload Section

Workload is the effort required to perform a task (operator load). Please rate the various mission segments of the experiment according to your perception of the demands made upon you. Rate each demand independent of your previous answers. All are rated from "Low = 0" to "High = 10". Please circle your response rating in Table G-1.

Table G-1 Workload Effort for DVI Operator Interface Evaluation Voice Input Trial Questionnaire

Name	Description	Mission Segment	Ratings from Low "0" to High "10"										
Visual Demand	Effort needed to gather all visual information required for each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9	10
		Re-tasking	0	1	2	3	4	5	6	7	8	9	10
Auditory Demand	Effort needed to gather all auditory information required for each mission segment.	Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10
		Transit and Recce	0	1	2	3	4	5	6	7	8	9	10
Mental Demand	Thinking and perceptual effort required for each mission segment.	Re-tasking	0	1	2	3	4	5	6	7	8	9	10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10
Physical Demand	Physical activity required for each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9	10
		Re-tasking	0	1	2	3	4	5	6	7	8	9	10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10
		Transit and Recce	0	1	2	3	4	5	6	7	8	9	10
		Re-tasking	0	1	2	3	4	5	6	7	8	9	10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10
		Transit and Recce	0	1	2	3	4	5	6	7	8	9	10
		Re-tasking	0	1	2	3	4	5	6	7	8	9	10

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DOC NO
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Table G-1 Workload Effort for DVI Operator Interface Evaluation Voice Input Trial Questionnaire

Name	Description	Mission Segment	Ratings from Low "0" to High "10"										
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10
Time Pressure	Degree of time pressure felt for each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9	10
		Re-tasking	0	1	2	3	4	5	6	7	8	9	10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10
Your Own Performance	Success at accomplishing the tasks of each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9	10
		Re-tasking	0	1	2	3	4	5	6	7	8	9	10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10
Effort	Overall level of effort, both physically and mentally, during each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9	10
		Re-tasking	0	1	2	3	4	5	6	7	8	9	10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10
Frustration	Level of frustration during each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9	10
		Re-tasking	0	1	2	3	4	5	6	7	8	9	10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10
Anxiety	Level of anxiety during each mission segment.	Transit and Recce	0	1	2	3	4	5	6	7	8	9	10
		Re-tasking	0	1	2	3	4	5	6	7	8	9	10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10

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HUMAN FACTORS ENGINEERING

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1000-1209

Table G-1 Workload Effort for DVI Operator Interface Evaluation Voice Input Trial Questionnaire

Name	Description	Mission Segment	Ratings from Low "0" to High "10"										
Global Workload	Considering all aspects, how would you rate the demands of the mission segments.	Re-tasking	0	1	2	3	4	5	6	7	8	9	10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10
		Transit and Recce	0	1	2	3	4	5	6	7	8	9	10
		Re-tasking	0	1	2	3	4	5	6	7	8	9	10
		Contact detection, Observation, and Report	0	1	2	3	4	5	6	7	8	9	10

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DVI Feedback Section

Feedback refers to all information provided by DVI, which allows you to assess or diagnose the current state of the system.

1. Using the rating scale below, rate how often during the mission you:

	Rarely	Occasionally	Sometimes	Frequently	Often
	1	2	3	4	5
a. looked at and/or attended to the DVI feedback display?				1	2 3 4 5
b. looked at and/or attended to the CDU?				1	2 3 4 5
c. looked at and/or attended to the DVI display soon after giving a DVI command?				1	2 3 4 5
d. looked at the CDU soon after giving a DVI command?				1	2 3 4 5
e. experienced visual conflicts? (e.g., you wanted to, but were unable to, look at the DVI feedback display and engine/cockpit instruments at the same time)				1	2 3 4 5
f. experienced auditory conflicts? (e.g., you wanted to, but were unable to, listen to a radio transmission and the DVI system beeps at the same time)				1	2 3 4 5

2. Using the scale below, indicate your opinion on the amount of feedback provided by the DVI system, in terms of:

	Far too little feedback	Slightly too little feedback	Appropriate amount	Slightly too much feedback	Far too much feedback
	1	2	3	4	5
a. visual feedback for a successful command				1	2 3 4 5
b. visual feedback for an error condition				1	2 3 4 5
c. auditory feedback for a successful command				1	2 3 4 5
d. auditory feedback for an error condition				1	2 3 4 5

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3. Using the rating scale below, rate each type of feedback in terms of allowing you to complete the tasks required. Circle your response.

	Completely Inadequate 1	Very Inadequate 2	Somewhat Inadequate 3	Neutral 4	Somewhat Adequate 5	Very Adequate 6	Completely Adequate 7
a. visual feedback for a successful command	1	2	3	4	5	6	7
b. visual feedback for an error condition	1	2	3	4	5	6	7
c. auditory feedback for a successful command	1	2	3	4	5	6	7
d. auditory feedback for an error condition	1	2	3	4	5	6	7

4. Using the rating scale below, rate each type of feedback in terms of allowing you to trouble-shoot the system. Circle your response.

	Completely Inadequate 1	Very Inadequate 2	Somewhat Inadequate 3	Neutral 4	Somewhat Adequate 5	Very Adequate 6	Completely Adequate 7
a. visual feedback for a successful command	1	2	3	4	5	6	7
b. visual feedback for an error condition	1	2	3	4	5	6	7
c. auditory feedback for a successful command	1	2	3	4	5	6	7
d. auditory feedback for an error condition	1	2	3	4	5	6	7

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5. Using the rating scale below, rate the ease of dividing your attention between the DVI feedback display and the outside visual scene and vice versa. Circle your response.

Very Easy
1

Easy 2

Borderline

Difficult
4

Very Difficult
5

6. Please list any additional comments you have about the feedback for the DVI system.

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CRM Section

7. Using the rating scale below, rate your degree of agreement/disagreement with the following statement. "I felt the division of duties between the flying and non-flying pilot was appropriate". Circle your response.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5

8. Using the rating scale below, rate the frequency of occurrence of the following:

Rarely	Occasionally	Sometimes	Frequently	Often
1	2	3	4	5

- | | | | | | |
|--|---|---|---|---|---|
| a. The other crewmember tried to take over duties that had been assigned to me in the new CRM model. | 1 | 2 | 3 | 4 | 5 |
| b. I forgot which duties to perform in the new CRM model. | 1 | 2 | 3 | 4 | 5 |

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Syntax Section

10. Please list any individual DVI vocabulary words, (e.g., calculate) that you felt were awkward or difficult to say, use, or remember during the mission you just performed.

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11. Please list any DVI commands, (e.g., Set Radio 1 118.1) that you felt were awkward or difficult to say, use, or remember during the mission you just completed.

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12. Please list any words or phrases that the DVI system had difficulty recognizing.

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DOC NO
1000-1209

ANNEX H
DVI OPERATOR INTERFACE TRIALS FINAL
QUESTIONNAIRE

31 Aug 00

ANNEX H
DVI OPERATOR INTERFACE TRIALS FINAL QUESTIONNAIRE

Final Questionnaire

Participant ID: _____

Date: _____

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Name: _____

Subject ID: _____

Background Information

This information helps us determine whether we have spoken to a broad sample of flight crews. To get an unbiased understanding of the concerns of the operation community, we must get feedback from a good cross-section of experience levels and backgrounds.

1. Age: _____
2. Years in CF: _____
3. (Estimated) Total Flight Hours _____
4. (Estimated) Total Griffon Hours _____
5. Are you _____ left or _____ right handed?
- 6a. Have you ever used speech recognition software or hardware before participating in this experiment?
Yes _____ No _____
- 6b. If yes, please briefly describe the system, e.g. name of software package, and its application, e.g. dictation for word processing.

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1. Using the rating scale below, please rate how acceptable manual input and direct voice input are for the crew completing each of the following tasks. Circle your response in Table H-1.

Unacceptable Major Deficiencies	Quite Unacceptable	Fairly Unacceptable	Neutral	Fairly Acceptable	Quite Acceptable	Totally Acceptable (Excellent)
1	2	3	4	5	6	7

Table H-1 Rating Scale for Manual Input and Direct Voice Input

Task	MI Rating						DVI Rating							
a. setting Radio to Preset 3	1	2	3	4	5	6	7	1	2	3	4	5	6	7
b. setting Radio 1 to 118.1	1	2	3	4	5	6	7	1	2	3	4	5	6	7
c. setting Radio 3 to FM	1	2	3	4	5	6	7	1	2	3	4	5	6	7
d. setting long range source to Doppler	1	2	3	4	5	6	7	1	2	3	4	5	6	7
e. changing to the 'Comm' header	1	2	3	4	5	6	7	1	2	3	4	5	6	7
f. activating a flight plan	1	2	3	4	5	6	7	1	2	3	4	5	6	7
g. activating the next leg of flight plan	1	2	3	4	5	6	7	1	2	3	4	5	6	7
h. activating present position direct to waypoint 12	1	2	3	4	5	6	7	1	2	3	4	5	6	7
i. activating present position direct to Home	1	2	3	4	5	6	7	1	2	3	4	5	6	7
j. displaying the Comm Summary page	1	2	3	4	5	6	7	1	2	3	4	5	6	7
k. displaying the flight plan route	1	2	3	4	5	6	7	1	2	3	4	5	6	7
l. displaying the data for waypoint 7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
m. displaying present position	1	2	3	4	5	6	7	1	2	3	4	5	6	7
n. switching to Radio 1	1	2	3	4	5	6	7	1	2	3	4	5	6	7
o. monitoring Nav A	1	2	3	4	5	6	7	1	2	3	4	5	6	7
p. monitoring all radios	1	2	3	4	5	6	7	1	2	3	4	5	6	7
q. stopping monitoring all Radios	1	2	3	4	5	6	7	1	2	3	4	5	6	7
r. isolating to Radio 3	1	2	3	4	5	6	7	1	2	3	4	5	6	7
s. calculating endurance and range	1	2	3	4	5	6	7	1	2	3	4	5	6	7

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2. Please rate which input mode you would prefer for each of the following tasks. Circle your response in Table H-2.

Table H-2 Task Rating for Input Mode

Task	Rating			
	Always MI	Usually MI	Equally MI & DVI	Always DVI
a. setting Radio to Preset 3	Always MI	Usually MI	Equally MI & DVI	Always DVI
b. setting Radio 1 to 118.1	Always MI	Usually MI	Equally MI & DVI	Always DVI
c. setting Radio 3 to FM	Always MI	Usually MI	Equally MI & DVI	Always DVI
d. setting long range source to Doppler	Always MI	Usually MI	Equally MI & DVI	Always DVI
e. changing to the 'Comm' header	Always MI	Usually MI	Equally MI & DVI	Always DVI
f. activating a flight plan	Always MI	Usually MI	Equally MI & DVI	Always DVI
g. activating the next leg of flight plan	Always MI	Usually MI	Equally MI & DVI	Always DVI
h. activating present position direct to waypoint 12	Always MI	Usually MI	Equally MI & DVI	Always DVI
i. activating present position direct to Home	Always MI	Usually MI	Equally MI & DVI	Always DVI
j. displaying the Comm Summary page	Always MI	Usually MI	Equally MI & DVI	Always DVI
k. displaying the flight plan route	Always MI	Usually MI	Equally MI & DVI	Always DVI
l. displaying the data for waypoint 7	Always MI	Usually MI	Equally MI & DVI	Always DVI
m. displaying present position	Always MI	Usually MI	Equally MI & DVI	Always DVI

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Table H-2 Task Rating for Input Mode

Task	Rating			
	Always MI	Usually MI	Equally MI & DVI	Always DVI
n. switching to Radio 1	Always MI	Usually MI	Equally MI & DVI	Always DVI
o. monitoring Nav A	Always MI	Usually MI	Equally MI & DVI	Always DVI
p. monitoring all radios	Always MI	Usually MI	Equally MI & DVI	Always DVI
q. stopping monitoring all Radios	Always MI	Usually MI	Equally MI & DVI	Always DVI
r. isolating to Radio 3	Always MI	Usually MI	Equally MI & DVI	Always DVI
s. calculating endurance and range	Always MI	Usually MI	Equally MI & DVI	Always DVI

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3. Two criteria were used to determine inclusion of DVI commands, using the rating scale below, please rate their importance. Circle your response.

Very Unimportant	Quite Unimportant	Fairly Unimportant	Neutral	Fairly Important	Quite Important	Very Important
1	2	3	4	5	6	7

Criteria

Rating

- | | | | | | | | |
|--|---|---|---|---|---|---|---|
| a. frequency of command use (included if high) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| b. potential to lower workload | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

4. Two criteria were used to determine exclusion of DVI commands, using the rating scale below, please rate their importance. Circle your response.

Very Unimportant	Quite Unimportant	Fairly Unimportant	Neutral	Fairly Important	Quite Important	Very Important
1	2	3	4	5	6	7

Criteria

Rating

- | | | | | | | | |
|---|---|---|---|---|---|---|---|
| a. complexity of task (excluded if high) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| b. potential for audio conflicts (excluded if high) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

5. Please list any other criteria you feel should be used when determining if a task should be implemented with DVI.

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6. Using the rating scale below, rate the impact of DVI compared to MI, on the following.
Circle your response.

Substantial Degradation	Slight Degradation	No Change	Slight Enhancement	Substantial Enhancement
1	2	3	4	5

	Rating				
a. your awareness of spatial orientation	1	2	3	4	5
b. your awareness of the crew	1	2	3	4	5
c. your awareness of aircraft systems	1	2	3	4	5
d. your awareness of the communication system	1	2	3	4	5
e. flight safety	1	2	3	4	5
f. mission effectiveness	1	2	3	4	5

7. Compared to MI, rate the impact of DVI on your eyes out time. Circle your response below.

Substantial Decrease	Slight Decrease	No Change	Slight Increase	Substantial Increase
1	2	3	4	5

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8. Please list any additional functionality that should be made available for a future DVI implementation in the Griffon.

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- 9 a. Which of the following approaches do you think would result in the most usable DVI system. Circle your response.
- (1) The DVI system is like a 4th crewmember – all commands issued to the DVI system and the resulting feedback are heard by all crewmembers.
 - (2) DVI is a private system – each crewmember hears only the commands (and the resulting feedback) that (s)he issues.
 - (3) A hybrid of (1) and (2) – each crewmember is provided with a “push for private” switch for the DVI system, and based on the revised CRM, some commands would be issued in private mode (e.g., monitor Radio 1), while others would be heard by everyone.
- 9b. Please explain your choice.

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- 10a. Rank the following DVI feedback alternatives from 1 (most preferable) to 6 (least preferable).

<u>Rank</u>	<u>Feedback Alternatives</u>
_____	synthesized speech
_____	synthesized speech with alerting tones
_____	visual display
_____	visual display with audio alerting tones
_____	visual display with synthesized speech
_____	visual display with audio tones and synthesized speech

- 10b. Please list any other feedback alternatives you feel should be considered for the DVI system.

[illegible]

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11. Do you feel that a DVI command (not display) should result in a page change on the CDU? For example, if you issue a "Set Radio 1 to 118.1" command while viewing the Flight Plan page, should the CDU change to the Radio 1 page? (Yes or No) Explain.

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12. In your view, is it worthwhile to pursue a DVI system for the CH146 Griffon? (Yes/No). Explain.

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ANNEX I

"MAGIC" SCRIPT FOR DVI OPERATOR INTERFACE EVALUATION

31 Aug 00

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1000-1209

ANNEX I - "MAGIC" SCRIPT FOR DVI OPERATOR INTERFACE EVALUATION

Table I-1 "MAGIC" Script For DVI Operator Interface Evaluation

Serial	Time	Phase	Activity
1.	0	Start-Up	W32 - "ZERO, this is Wolf 32, ready for take-off, over" ZERO - "Wolf 32, you are cleared take-off, wind 090 at 15, altimeter 3015, over" W32 - "Wolf 32 cleared take-off, out"
2.	2:00	Take-Off	
3.	2:10	Transit to Start Point	
4.	2:15	Call Leaving the zone	W32 - "ZERO, this is Wolf 32, departing the zone over" ZERO - "Wolf 32, contact MAGIC, 120.7, over" W32 - "Wolf 32, out"
5.	2:45	Arrive at starting point	
6.	2:45	Start Road Recce	
7.	3:30	Call 'on task'	W32 - "MAGIC, this is Wolf 32, over" MAGIC - "Wolf 32 this is MAGIC, go ahead, over" W32 - "Wolf 32, by ACP 2, on task, over" MAGIC - "Wolf 32, roger, out"
8.	4:00	Cross Phase Line	W32 - "MAGIC, this is Wolf 32, over" MAGIC - "Wolf 32 this is MAGIC, go ahead, over" W32 - "Wolf 32, crossing Apple on Alpha Sierra 165 Romeo, over" MAGIC - "Wolf 32, roger, out"

Table I-1 "MAGIC" Script For DVI Operator Interface Evaluation

Serial	Time	Phase	Activity
9.	4:30	Crew sees contact	W32 - "MAGIC this is Wolf 32, we see a contact, looks like a burning vehicle of some kind, requesting further instructions, over" MAGIC - "Wold 32 try to get a closer look, for your contact report, switch to alternate MAGIC frequency 118.1, over" W32 - "Switching to MAGIC on 118.1, out" W32 - "MAGIC this is Wolf 32 on 118.1, over" MAGIC - " W32 go ahead, over" W32 - " We are moving in for a contact report, wait, out."
10.	4:40	Manouver into observation position	
11.	5:25	Arrive in observation position	
12.	5:35	Unmask and determine contact information	
13.	6:10	Prepare contact report	
14.	6:50	Send contact report	W32 - " This is Wolf 32, contact report, over" MAGIC - "Wolf 32, this is MAGIC, go ahead, over" W32 - "S/A/L/U/T/E, request further instructions (should we move in closer)" MAGIC - "Wolf 32, (negative india 29 is already taking care of this) proceed on route, over" W32 - "Wolf 32, proceeding on route, out"
15.	7:50	Switch back to 120.7 for re-tasking	MAGIC - "Wolf 32, this is MAGIC, switch to 120.7 for re-tasking, over" W32 - "Wolf 32, roger, switching to 120.7, out"
16.	8:05	Stand by for re-tasking	W32 - "MAGIC, this is Wolf 32 on 120.7, over" MAGIC - "Wolf 32, this is MAGIC, stand by for re-tasking, over" W32 - "Roger, over"

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HUMAN FACTORS ENGINEERING

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Table I-1 "MAGIC" Script For DVI Operator Interface Evaluation

Serial	Time	Phase	Activity
17.	8:35	Re-task for second leg of recce	MAGIC - "Wolf 32, your mission routing has been changed. Your new routing upon completion of arriving at ACP # is from ACP # to ACP # via ####. Objectives remain the same as current route. Remainder of Helitask remains the same, read back over" W32 - "Wolf 32, we copy, after completion of current route, new route, ACP # to ACP # via ####, over" MAGIC - "Wolf 32, roger out"
18.	9:15	Plan Second Leg	
19.	10:15	Continue First Leg	
20.	10:15	Contact MAGIC 'back on task'	W32 - "MAGIC, this is Wolf 32, continuing route, over" MAGIC - "Wolf 32, roger out"
21.	11:20	Arrive at end of First Leg	W32 - "MAGIC, this is Wolf 32, Primary Route completed, proceeding to alternate route, over" MAGIC - "Wolf 32, roger"
22.	11:20	Transit to start point of second leg	MAGIC - "Wolf 32, this is MAGIC, come up 118.1 for alternate MAGIC frequency, over" W32 - "Wolf 32 switching 118.1, out" W32 - "MAGIC this is Wolf 32 on 118.1, over" MAGIC - "Wolf 32, Squawk ident" MAGIC - "Wolf 32, you're identified, proceed on route, over" W32 - "Wolf 32, roger out"
23.	12:15	Arrive at start point of 2 nd leg	
24.	12:45	Call MAGIC on 'on task'	W32 - "MAGIC, this is Wolf 32, by ACP #, commencing alternate route, over" MAGIC - "Wolf 32, roger"

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Table I-1 "MAGIC" Script For DVI Operator Interface Evaluation

Serial	Time	Phase	Activity
25.	13:35	Crew sees contact	W32 - MAGIC, this is Wolf 32, contact, looks like a burning vehicle, requesting further instructions, over" MAGIC - "Wolf 32, try to get a closer look, for your contact report switch to alternate MAGIC frequency on 120.7, over" W32 - "Wolf 32 switching over 120.7, out" W32 - "MAGIC, this is Wolf 32 on 120.7, over" MAGIC - "W32, this is MAGIC, go ahead, over" W32 - "Contact, wait, out."
26.	13:55	Manouver into observation position	
27.	14:15	Cross Phase Line	W32 - "MAGIC, this is Wolf 32, over" MAGIC - "Wolf 32 this is MAGIC, go ahead, over" W32 - "Wolf 32, crossing Apple on AS165R" MAGIC - "Wolf 32, roger, out"
28.	15:30	Arrive in observation position	
29.	15:35	Unmask to observe contact	
30.	16:30	Prepare contact report	
31.	17:00	Send contact report	W32 - "This is Wolf 32, contact report, over" MAGIC - "Wolf 32, this is MAGIC, go ahead, over" W32 - "S/A/L/U/T/E" request further instructions (should we move in closer) MAGIC - "Wolf 32, (negative India 32 is already taking care of this) proceed on route, over" W32 - "Wolf 32, proceeding on route, out"

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DOC NO
1000-1209

Table I-1 "MAGIC" Script For DVI Operator Interface Evaluation

Serial	Time	Phase	Activity
32.	17:10	Told to switch to alternate MAGIC freq	MAGIC - "Wolf 32, this is MAGIC, switch to 118.1, over" W32 - "Wolf 32, switching 118.1, out" W32 - "MAGIC, this is Wolf 32, on 118.1 over"
33.	17:55	Continue route	
34.	18:15	Send 'back on task'	W32 - "MAGIC, this is Wolf 32, back on task, over" MAGIC - "Wolf 32, roger"
35.	19:00	Finish route	
36.	19:00	Return Home	
37.	19:20	Send 'Mission complete'	W32 - "MAGIC, this is Wolf 32, mission complete, returning to base, over" MAGIC - "Wolf 32, roger"
38.	19:40	Request to switch to AWACS	MAGIC - "Wolf 32, this is MAGIC, switch to alternate MAGIC frequency 120.7, over" W32 - "Wolf 32, switching to 120.7, out" W32 - "MAGIC, this is Wolf 32, over"
39.	19:45	Queried by MAGIC for endurance and range for possible CSAR	MAGIC - "Wolf 32, this is MAGIC, for a possible CSAR, we require your endurance and range, over" W32 - "Wolf 32, wait, out"
40.	19:55	Calculate endurance and range	
41.	20:15	Send information to MAGIC	W32 - "MAGIC, this is Wolf 32, endurance is 2 hours 5 minutes, range is 230 nm, over" MAGIC - "Wolf 32, roger, out"
42.	20:20	Cancel CSAR	MAGIC - "Wolf 32 this is MAGIC, you are no longer required for CSAR, return to Home Plate, over" W32 - "Wolf 32, returning Home plate, out"

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Table I-1 "MAGIC" Script For DVI Operator Interface Evaluation

Serial	Time	Phase	Activity
43.	20:40	Contact ZERO for Landing	W32 - "ZERO, this is Wolf 32, entering your zone from the East, over" ZERO - "Wolf 32 this is zero, roger, call on final for landing, altimeter 3015, over" W32 - "Wolf 32, roger" W32 - "Wolf 32 is final for the pad" ZERO - "Wolf 32, you are cleared to land, wind 090 at 12, over" W32 - "Wolf 32, roger"
44.	22:00	Land at Sqn Location	

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ANNEX J

"ZERO" SCRIPT FOR DVI OPERATOR INTERFACE EVALUATION

31 Aug 00

ANNEX J - "ZERO" SCRIPT FOR DVI OPERATOR INTERFACE EVALUATION

Table J-1 "ZERO" Script for DVI Operator Interface Evaluation

Serial	Time	Phase	Activity
1.	0	Start-Up	W32 - "ZERO, this is Wolf 32, ready for take-off, over" ZERO - "Wolf 32, you are cleared take-off, wind 090 at 15, altimeter 3015, over" W32 - "Wolf 32 cleared take-off, out"
2.	2:00	Take-Off	
3.	2:10	Transit to Start Point	
4.	2:15	Call Leaving the zone	W32 - "ZERO, this is Wolf 32, departing the zone over" ZERO - "Wolf 32, contact MAGIC, 120.7, over" W32 - "Wolf 32, out"
5.	2:45	Arrive at starting point	
6.	2:45	Start Road Recce	
7.	3:30	Call 'on task'	W32 - "MAGIC, this is Wolf 32, over" MAGIC - "Wolf 32 this is MAGIC, go ahead, over" W32 - "Wolf 32, by ACP 2, on task, over" MAGIC - "Wolf 32, roger, out"
8.	4:00	Cross Phase Line	W32 - "MAGIC, this is Wolf 32, over" MAGIC - "Wolf 32 this is MAGIC, go ahead, over" W32 - "Wolf 32, crossing Apple on Alpha Sierra 165 Romeo, over" MAGIC - "Wolf 32, roger, out"

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HUMAN FACTORS ENGINEERING

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Table J-1 "ZERO" Script for DVI Operator Interface Evaluation

Serial	Time	Phase	Activity
9.	4:30	Crew sees contact	W32 - "MAGIC this is Wolf 32, we see a contact, looks like a burning vehicle of some kind, requesting further instructions, over" MAGIC - "Wold 32 try to get a closer look, for your contact report, switch to alternate MAGIC frequency 118.1, over" W32 - "Switching to MAGIC on 118.1, out" W32 - "MAGIC this is Wolf 32 on 118.1, over" MAGIC - " W32 go ahead, over" W32 - " We are moving in for a contact report, wait, out."
10.	4:40	Manouver into observation position	
11.	5:25	Arrive in observation position	
12.	5:35	Unmask and determine contact information	
13.	6:10	Prepare contact report	
14.	6:50	Send contact report	W32 - " This is Wolf 32, contact report, over" MAGIC - "Wolf 32, this is MAGIC, go ahead, over" W32 - "S/A/L/U/T/E, request further instructions (should we move in closer)" MAGIC - "Wolf 32, (negative india 29 is already taking care of this) proceed on route, over" W32 - "Wolf 32, proceeding on route, out"
15.	7:50	Switch back to 120.7 for re-tasking	MAGIC - "Wolf 32, this is MAGIC, switch to 120.7 for re-tasking, over" W32 - "Wolf 32, roger, switching to 120.7, out"
16.	8:05	Stand by for re-tasking	W32 - "MAGIC, this is Wolf 32 on 120.7, over" MAGIC - "Wolf 32, this is MAGIC, stand by for re-tasking, over" W32 - "Roger, over"

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HUMAN FACTORS ENGINEERING

DOC NO
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Table J-1 "ZERO" Script for DVI Operator Interface Evaluation

Serial	Time	Phase	Activity
17.	8:35	Re-task for second leg of recon	MAGiC - "Wolf 32, your mission routing has been changed. Your new routing upon completion of arriving at ACP # is from ACP # to ACP # via #####. Objectives remain the same as current route. Remainder of Helitask remains the same, read back over" W32 - "Wolf 32, we copy, after completion of current route, new route, ACP # to ACP # via #####, over" MAGiC - "Wolf 32, roger out"
18.	9:15	Plan Second Leg	
19.	10:15	Continue First Leg	
20.	10:15	Contact MAGiC 'back on task'	W32 - "MAGiC, this is Wolf 32, continuing route, over" MAGiC - "Wolf 32, roger out"
21.	11:20	Arrive at end of First Leg	W32 - "MAGiC, this is Wolf 32, Primary Route completed, proceeding to alternate route, over" MAGiC - "Wolf 32, roger"
22.	11:20	Transit to start point of second leg	MAGiC - "Wolf 32, this is MAGiC, come up 118.1 for alternate MAGiC frequency, over" W32 - "Wolf 32 switching 118.1, out" W32 - "MAGiC this is Wolf 32 on 118.1, over" MAGiC - "Wolf 32, Squawk ident" MAGiC - "Wolf 32, you're identified, proceed on route, over" W32 - "Wolf 32, roger out"
23.	12:15	Arrive at start point of 2 nd leg	
24.	12:45	Call MAGiC on 'on task'	W32 - "MAGiC, this is Wolf 32, by ACP #, commencing alternate route, over" MAGiC - "Wolf 32, roger"

BAE SYSTEMS CANADA INC
HUMAN FACTORS ENGINEERING

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Table J-1 "ZERO" Script for DVI Operator Interface Evaluation

Serial	Time	Phase	Activity
25.	13:35	Crew sees contact	W32 - MAGIC, this is Wolf 32, contact, looks like a burning vehicle, requesting further instructions, over" MAGIC - "Wolf 32, try to get a closer look, for your contact report switch to alternate MAGIC frequency on 120.7, over" W32 - "Wolf 32 switching over 120.7, out" W32 - "MAGIC, this is Wolf 32 on 120.7, over" MAGIC - "W32, this is MAGIC, go ahead, over" W32 - "Contact, wait, out."
26.	13:55	Manouver into observation position	
27.	14:15	Cross Phase Line	W32 - "MAGIC, this is Wolf 32, over" MAGIC - "Wolf 32 this is MAGIC, go ahead, over" W32 - "Wolf 32, crossing Apple on AS165R" MAGIC - "Wolf 32, roger, out"
28.	15:30	Arrive in observation position	
29.	15:35	Unmask to observe contact	
30.	16:30	Prepare contact report	
31.	17:00	Send contact report	W32 - "This is Wolf 32, contact report, over" MAGIC - "Wolf 32, this is MAGIC, go ahead, over" W32 - "S/A/L/U/T/E" request further instructions (should we move in closer) MAGIC - "Wolf 32, (negative India 32 is already taking care of this) proceed on route, over" W32 - "Wolf 32, proceeding on route, out"

Table J-1 "ZERO" Script for DVI Operator Interface Evaluation

Serial	Time	Phase	Activity
32.	17:10	Told to switch to alternate MAGIC freq	MAGIC - "Wolf 32, this is MAGIC, switch to 118.1, over" W32 - "Wolf 32, switching 118.1, out" W32 - "MAGIC, this is Wolf 32, on 118.1 over"
33.	17:55	Continue route	
34.	18:15	Send 'back on task'	W32 - "MAGIC, this is Wolf 32, back on task, over" MAGIC - "Wolf 32, roger"
35.	19:00	Finish route	
36.	19:00	Return Home	
37.	19:20	Send 'Mission complete'	W32 - "MAGIC, this is Wolf 32, mission complete, returning to base, over" MAGIC - "Wolf 32, roger"
38.	19:40	Request to switch to AWACS	MAGIC - "Wolf 32, this is MAGIC, switch to alternate MAGIC frequency 120.7, over" W32 - "Wolf 32, switching to 120.7, out" W32 - "MAGIC, this is Wolf 32, over"
39.	19:45	Queried by MAGIC for endurance and range for possible CSAR	MAGIC - "Wolf 32, this is MAGIC, for a possible CSAR, we require your endurance and range, over" W32 - "Wolf 32, wait, out"
40.	19:55	Calculate endurance and range	
41.	20:15	Send information to MAGIC	W32 - "MAGIC, this is Wolf 32, endurance is 2 hours 5 minutes, range is 230 nm, over" MAGIC - "Wolf 32, roger, out"
42.	20:20	Cancel CSAR	MAGIC - "Wolf 32 this is MAGIC, you are no longer required for CSAR, return to Home Plate, over" W32 - "Wolf 32, returning Home plate, out"

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Table J-1 "ZERO" Script for DVI Operator Interface Evaluation

Serial	Time	Phase	Activity
43.	20:40	Contact ZERO for Landing	W32 - "ZERO, this is Wolf 32, entering your zone from the East, over" ZERO - "Wolf 32 this is ZERO, roger, call on final for landing, altimeter 3015, over" W32 - "Wolf 32, roger" W32 - "Wolf 32 is final for the pad" ZERO - "Wolf 32, you are cleared to land, wind 090 at 12, over" W32 - "Wolf 32, roger"
44.	22:00	Land at Sqn Location	

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ANNEX K

**ETHICS COMMITTEE APPLICATION, INFORMED CONSENT
AND DEBRIEFING FORMS**

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ANNEX K

ETHIC COMMITTEE APPLICATION, INFORMED CONSENT AND DEBRIEFING FORM

K.1 ETHICS COMMITTEE APPLICATION

K.1.1 Purpose of the research

The CH146 Griffon is a multiple purpose helicopter used for search and rescue, and transportation operations, as well as providing aid to other agencies. It is a three-crew helicopter comprised of a pilot, co-pilot and flight engineer. Currently the core of the avionics system architecture is a BAE SYSTEMS CANADA INC. (BSC) (formerly Canadian Marconi Company(CMC)) Control and Display Unit (CDU). The location and method of operation of the CDU requires extended head-down operation by the crew, which is believed to have flight safety implications. The purpose of this research is to compare the existing manually controlled CH146 Griffon cockpit configuration versus a proposed Direct Voice Input (DVI) equipped cockpit. It is hypothesized that the introduction of DVI will improve mission effectiveness and flight safety in the Griffon. In this experiment, head-up/head-down time will be used as an indicator of flight safety while task completion time, mission completion time, and subjective assessments of workload will be used as indicators of mission effectiveness.

K.1.2 Procedure

Participants will be required to "fly" and act as a co-pilot in BSC's Aircraft Crewstation Demonstrator (ACD) over a two-day period. The ACD is a rapidly re-configurable prototyping facility that will be configured as a CH146 Griffon helicopter. Each flight will follow typical mission profiles where pilots will be required to perform flight tasks such as changing radios, calculating fuel requirements, and following orders from a tasking agency. Participants will be required to complete each flight using both the currently used CDU and a DVI interface under two noise conditions (no noise versus radio traffic). Furthermore, participants will repeat the same flight with the addition of an audio and visual target discrimination task. Based on characteristics of the targets (colour for visual, pitch for audio) participants are to indicate, through the use of a push button, whether or not a target or non-target was presented. Throughout the trials, a head tracker will be used in order to measure head position.

K.1.3 Materials

The basic flight deck structure of the ACD contains a pair of aircraft seats equipped with representative flight controls (centre stick, throttle quadrant and rudder pedals). The external scene is presented on a rear-projection screen situated approximately 3 m in front of the participants. The aircraft instrument panel is presented as an electronic prototype on three large, high-resolution computer monitors equipped with a touch screen interface for control input. The simulated CDUs are located on the centre pedestal and consist of a computer monitor and keypad. The speech recognition units will be speaker-dependent Verbex Speech Commander

portables with the manufacturer-supplied headsets and microphones. Each participant will have complete control of the headset volume. Ambient aircraft noise will be presented over two small speakers (< 60 dBA) positioned at the rear of the ACD. Auditory feedback (tones), radio traffic and intercom chatter will be presented over the Verbex headsets. Four-line by twenty-character Liquid Crystal Displays (LCDs) will be used to present visual feedback for the speech recognition system to both the pilot and co-pilot. The LCDs will be positioned approximately 70 cm (10° visual angle) directly in front of each participant on the glare shield of the ACD. Participants will be completing a number of questionnaires regarding their experiences using the two input systems.

K.1.4 Participants

Six crews, each comprised of two Canadian Forces (CF) CH146 Giffon pilots, will take part in the study. Participants will be volunteers from CF Squadron 427 based at Canadian Forces Base (CFB) Petawawa.

K.1.5 Informed Consent

Subjects are given a written informed consent from which they are to read and sign if they wish to participate. A sample consent is included in Annex K.

K.1.6 Confidentiality

All data collected in this experiment will be kept strictly confidential through the assignment of a coded identification number. The information provided would be used for research purposes only and no participant will be identified by name in any research reports produced from this study. Further, the information provided is made available only to the researchers associated with this experiment.

K.1.7 Debriefing

Each subject will be given a written and verbal debriefing. A sample debriefing form is attached in Subsection K.3.

K.1.8 Announcement for Recruitment

As specified in Public Works and Government Services Canada (PWGSC) file 03SV.W8477-8-AC40, the Department of National Defence will solicit for volunteers to participants in this experiment. Participants will be considered to be on paid duty while participating in this study.

K.1.9 Potential Risks and Discomfort

Flying is a high-workload task. To minimize ongoing demands, the duration of each flying session has been limited to 45 minutes and sessions have been spread out over a period of two days.

K.2 CONSENT FORM

Study: Direct Voice Input vs. Manual Control in the CH146 Griffon.

Faculty Sponsor: Dr. Chris M. Herdman, Ph.D., Department of Psychology,
Carleton University, Tel. (613) 520-2600 x 8122.

The purpose of this informed consent form is to ensure that you understand both the purpose of the study and the nature of your participation in it. The informed consent must provide you with enough information such that you have the opportunity to determine whether you wish to participate in the study. Please ask the researcher to clarify any concerns that you may have after reading this form.

K.2.1 Research Personnel

The following people are involved in this research project and may be contacted at any time should you require further information about this study:

Faculty Sponsor:	Dr. Chris M. Herdman (613-520-2600 x 8122)
Principal Investigator:	Ms. L. Lessard (613-520-2600 x 2696)
Project Engineer:	Mr. Murray Gamble, CMC (613-592-6500)
Scientific Authority:	Dr. P. Farrell, Defence and Civil Institute of Environmental Medicine (416-635-2169)

Should you have any ethical concerns regarding this study, you may contact one for the following individuals:

Kimberly Matheson, Ph.D.	Chair, Psychology Department (613-520-2600 x 2648)
Mary Gick, Ph.D.	Chair, Ethics Committee (613-520-2600 x 2664)

K.2.2 Purpose

The purpose of the study is to assess mission effectiveness and flight safety using the existing CH146 Griffon manual CDU interface compared to a DVI interface.

K.2.3 Task Requirements

In this study, you will be required to act as both the flying and non-flying pilots during mission-based scenarios in the ACD. You will be asked to perform flight tasks such as changing radios, calculating fuel requirements, and following orders from a tasking agency using the CDU and a DVI interface under varying noise conditions. You will also be required to perform a target discrimination task for both audio and visual targets. After each interface type, you will be asked to complete questionnaires regarding your experiences.

K.2.4 Duration and Locale

The experimental session will last approximately two days. Approximately 8.5 hours over the two days will be spent in the cockpit, alternating between flying and non-flying duties. The remainder of the time will be spent learning to use the speech recognition system and completing questionnaires. The testing will take place at BSC in Kanata, ON.

K.2.5 Potential Risks and Discomfort

Flying is a high-workload task. To minimize ongoing demands the duration of each flying session has been limited to 45 minutes. Please note that we are not evaluating your flying skills; we are simply interested in assessing your relative performance using manual input versus DVI.

The principle risk of the experiment is a feeling of motion sickness, including nausea and headache. There is also a risk of eye fatigue, such as that associated with viewing a video display. Participation in this study, or indeed in any research, may involve risks that are currently unforeseen.

K.2.6 Anonymity and Confidentiality

All data collected in this experiment will be kept strictly confidential through the assignment of a coded identification number. The information provided will be used for research purposes only and you will not be identified by name in any research reports produced from this study. Further, the information provided is made available only to the researchers associated with this experiment.

K.2.7 Right to Withdraw/Omit

You will be permitted to omit any question(s) that you choose not to answer. Participation in this study is entirely voluntary and you may decide to stop participating at any time without any consequences to your career.

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K.2.8 Declaration

I have read the above description of the study examining DVI in the CH146 Griffon; I understand the conditions of my participation.

I understand that the principle risk of the experiment is a feeling of motion sickness, including nausea and headache. There is also a risk of eye fatigue, such as that associated with viewing a video display. In the highly unlikely event that I become injured during my participation, I agree to go with the experimenter to obtain medical treatment. Finally, I acknowledge that my participation in this study, or indeed in any research, may involve risks that are currently unforeseen. I understand and accept these risks.

I am aware that my vision and balance may be temporarily affected by any virtual reality experience, and I agree not to drive or operate dangerous machinery for a period of one hour. If I experience side effects from this virtual reality experience, I will return and report this to the experimenter. If, in the unlikely event that I become incapacitated during my participation, I hereby consent to whatever medical intervention that is required.

My signature indicates that I hereby consent to participate in this experiment.

Name of Participant

Name of Witness

Participant's Signature

Witness's Signature

Date

Date

K.3 DEBRIEFING

The purpose of this research is to compare the existing manually controlled CH146 Griffon cockpit configuration versus a proposed DVI equipped cockpit. It is hypothesized that the introduction of DVI will improve mission effectiveness and flight safety in the Griffon. In this experiment, head-up/head-down time will be used as an indicator of flight safety while task completion time, mission completion time, and subjective assessments of workload will be used as indicators of mission effectiveness.

The current location and method of operation of the CH146 CDU requires extended head-down operation by the pilot in some circumstances, which has been found to have flight safety implications in the tactical helicopter environment, particularly in bad weather or when using Night Vision Goggles (NVGs).

One technology that may address this issue is DVI. DVI has the potential to reduce the amount of time that the pilot has to direct visual attention to controls and displays in the cockpit. In high workload applications where the crew's attention must be directed outside the cockpit, DVI has the potential to not only improve mission effectiveness, but also to improve operational mission safety margins.

In addition to measuring "head-down" time, the target detection task was designed to evaluate possible competing visual and auditory demands associated with each system. The introduction of DVI into the Griffon cockpit may introduce auditory conflicts; however, this must be balanced against the visual conflicts that exist with the current CDU. Therefore, care must be taken to evaluate the strengths and weaknesses associated with each system.

If DVI is demonstrated to increase flight safety and/or mission effectiveness through increased head-up time, further research will be conducted with the aim of implementing a fully-functional DVI system in the CH146 Griffon.

We would like to thank you for your participation in this research. Your time and effort are greatly appreciated!

If you have any questions or comments about this research, please feel free to contact any of the following individuals:

Ms. L. Lessard	Researcher, Psychology Department, Carleton University	613-520-2600 x 2696
Dr. C.M. Herdman	Faculty Advisor, Psychology Department, Carleton University	613-520-2600 x 8122
Mr. M. Gamble	Project Engineer, Canadian Marconi Company	613-592-6500
Dr. P. Farrell	Scientific Authority, Defence and Civil Institute of Environmental Medicine	416-635-2169

Should you have any ethical concerns regarding this study, you may contact:

Kimberly Matheson, Ph.D.	Chair of the Psychology Department	613-520-2600 x 2648
Mary Gick, Ph.D.	Chair of the Ethics Committee	613-520-2600 x 2664

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ANNEX L
SAMPLE MISSION MAP

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ANNEX L – SAMPLE MISSION MAP

A sample map is included in Figure L-1. A legend explaining the map markings is presented below in Table L-1. The sample map illustrates the flow of the mission. The only markings appearing on the map when the mission begins are the black lines, representing the routing, and the phase line, an airspace control measure. The targets are added to the map as they are encountered by the crew. The red lines, indicating the revised routing, are added after MAGIC provides the re-tasking information to the aircrew. The event markers "A" and "B" represent the approximate point in the mission when the two tasking requests are made, and appear only on the experimenters' maps. The two tasking requests are driven by location, not time, to ensure similar workload for all crews participating in the experiment.

Table L-1 Legend for Sample Mission Map

Marking	Description
Solid Lines	Direct path between waypoints, e.g. WP2 to WP5
Dashed Lines	Actual path to be flown between waypoints, e.g. along the road between WP2 and WP5
Black Lines	Planned routing, generated during pre-mission planning
Red Lines	Revised routing, based on in-flight re-tasking by MAGIC
	Event: In-flight re-tasking by MAGIC
	Event: Call for possible CSAR by MAGIC
	Target #1
	Target #2
"Apple"	Phase Line (airspace control measure)

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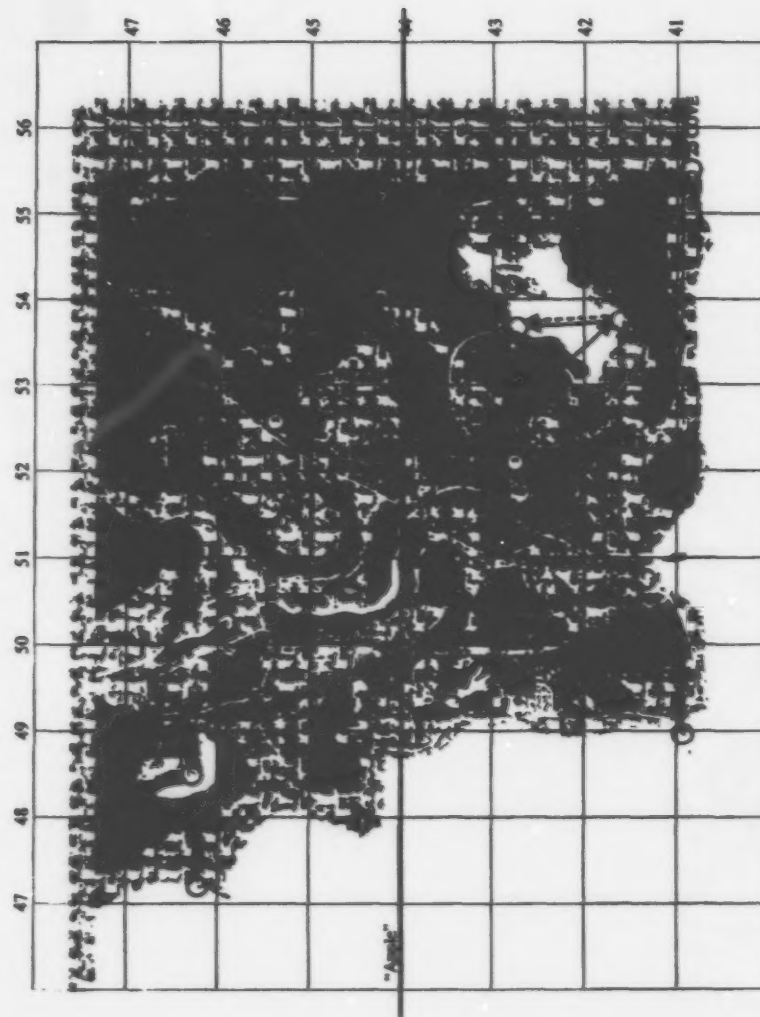


Figure L-1 Sample Mission Map

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ANNEX M
QUESTIONNAIRE RATING SCALE RESULTS

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ANNEX M – QUESTIONNAIRE RATING SCALE RESULTS

M.1 MANUAL INPUT QUESTIONS

M.1.1 Feedback Section

M.1.1.1 Question 1

Using the rating scale below, rate how often during the mission you:

Question	Non-Flying Pilots' Results				
	Rarely (1)	Occasionally (2)	Sometimes (3)	Frequently (4)	Often (5)
a. looked at and/or attended to the CDU?	0	0	0	3	9
b. looked at and/or attended to the CDU soon after inputting a MI command?	0	1	1	4	6
c. experienced visual conflicts?	3	2	4	2	1
d. experienced auditory conflicts?	5	3	1	2	1
					Often (5) Frequently/often (4.5) Sometimes (3) Occasionally (2)

Question	Flying Pilots' Results				
	Rarely (1)	Occasionally (2)	Sometimes (3)	Frequently (4)	Often (5)
a. looked at and/or attended to the CDU?	9	3	0	0	0
b. looked at and/or attended to the CDU soon after inputting a MI command?	11	1	0	0	0
c. experienced visual conflicts?	9	1	1	1	0
d. experienced auditory conflicts?	4	3	3	2	0
					Rarely (1) Rarely (1) Rarely (1) Occasionally (2)

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M.1.1.2 Question 2

Rate the amount of feedback provided by the CDU.

Role	Far Too Little Feedback (-2)	Slightly Too Little Feedback (-1)	Appropriate Amount (0)	Slightly Too Much Feedback (1)	Far Too Much Feedback (2)	Median
Non-Flying Pilots	0	2	10	0	0	Appropriate Amount (0)
Flying Pilots	3	0	9	0	0	Appropriate Amount (0)

M.1.1.3 Question 3

Rate the CDU feedback in terms of allowing you to complete the tasks required.

Role	Completely Inadequate (-3)	Very Inadequate (-2)	Somewhat Inadequate (-1)	Neutral (0)	Somewhat Adequate (1)	Very Adequate (2)	Completely Adequate (3)	Median
Non-Flying Pilots	0	1	1	1	4	4	1	Somewhat Adequate (1)
Flying Pilots*	0	0	1	7	1	2	0	Neutral (0)

- P(1) acting as flying pilot did not respond to this question

M.1.1.4 Question 4

Rate the CDU in terms of allowing you to trouble-shoot the system.

Role	Completely Inadequate (-3)	Very Inadequate (-2)	Somewhat Inadequate (-1)	Neutral (0)	Somewhat Adequate (1)	Very Adequate (2)	Completely Adequate (3)	Median
Non-Flying Pilots	0	0	3	2	2	5	0	Somewhat Adequate (1)
Flying Pilots*	0	0	2	7	1	1	0	Neutral (0)

- P(1) acting as flying pilot did not respond to this question

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M.1.1.5 Question 5

Rate the ease of dividing your attention between the CDU and the outside visual scene and vice versa.

Role	Very Difficult (-2)	Difficult (-1)	Borderline (0)	Easy (1)	Very Easy (2)	Median
Non-Flying Pilot	0	5	5	2	0	Borderline (0)
Flying Pilot*	0	1	5	4	1	Borderline (0)

- P(1) acting as flying pilot did not respond to this question

M.2 DVI Questionnaire

M.2.1 Feedback Section

M.2.1.1 Question 1

Using the rating scale below, rate how often during the mission you:

Question	Non-Flying Pilots' Results					
	Rarely (1)	Occasionally (2)	Sometimes (3)	Frequently (4)	Often (5)	Median
a. looked at and/or attended to the DVI feedback display?	0	0	2	7	3	Frequently (4)
b. looked at and/or attended to the CDU?	1	8	3	0	0	Occasionally (2)
c. looked at and/or attended to the DVI feedback display soon after giving a DVI command?	0	0	0	5	7	Often (5)
d. looked at the CDU soon after giving a DVI command?	5	5	2	0	0	Occasionally (2)
e. experienced visual conflicts?	8	2	2	0	0	Rarely (1)
f. experienced auditory conflicts?	8	2	0	2	0	Rarely (1)

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Flying Pilots' Results						
Question	Rarely (1)	Occasionally (2)	Sometimes (3)	Frequently (4)	Often (5)	Median
a. looked at and/or attended to the DVI feedback display?	0	1	5	6	0	Sometimes/Frequently (3.5)
b. looked at and/or attended to the CDU?	8	3	1	0	0	Rarely (1)
c. looked at and/or attended to the DVI feedback display soon after giving a DVI command?	1	1	1	2	7	Often (5)
d. looked at the CDU soon after giving a DVI command?	7	5	0	0	0	Rarely (1)
e. experienced visual conflicts?	6	4	1	1	0	Rarely/Occasionally (1.5)
f. experienced auditory conflicts?	6	2	3	1	0	Rarely/Occasionally (1.5)

M.2.1.2 Question 2

Rate the amount of feedback provided by the DVI system, in terms of:

Non-Flying Pilots' Results						
Question	Far Too Little Feedback (-2)	Slightly Too Little Feedback (-1)	Appropriate Amount (0)	Slightly Too Much Feedback (1)	Far Too Much Feedback (2)	Median
a. visual feedback for a successful command	0	1	11	0	0	Appropriate Amount (0)
b. visual feedback for an error condition	1	3	8	0	0	Appropriate Amount (0)
c. auditory feedback for a successful command	1	1	10	0	0	Appropriate Amount (0)
d. auditory feedback for an error condition	2	2	8	0	0	Appropriate Amount (0)

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Flying Pilots' Results						
Question	Far Too Little Feedback (-2)	Slightly Too Little Feedback (-1)	Appropriate Amount (0)	Slightly Too Much Feedback (1)	Far Too Much Feedback (2)	Median
a. visual feedback for a successful command	0	1	10	1	0	Appropriate Amount (0)
b. visual feedback for an error condition	1	5	5	1	0	Appropriate Amount/ Slightly Too Little Feedback (-0.5)
c. auditory feedback for a successful command	0	3	8	1	0	Appropriate Amount (0)
d. auditory feedback for an error condition	0	4	7	1	0	Appropriate Amount (0)

M.2.1.3 Question 3

Rate each type of feedback in terms of allowing you to complete the tasks required.

Non-Flying Pilots' Results						
Question	Completely Inadequate (-3)	Very Inadequate (-2)	Somewhat Inadequate (-1)	Neutral (0)	Somewhat Adequate (1)	Very Adequate (2)
a. visual feedback for a successful command	0	0	1	2	2	Very Adequate (2)
b. visual feedback for an error condition	0	0	5	3	2	Neutral (0)
c. auditory feedback for a successful command	0	1	1	3	2	Somewhat Adequate (1)
d. auditory feedback for an error condition	0	2	3	5	2	Neutral (0)

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Flying Pilots' Results								
Question	Completely Inadequate (-3)	Very Inadequate (-2)	Somewhat Inadequate (-1)	Neutral (0)	Somewhat Adequate (1)	Very Adequate (2)	Completely Adequate (3)	Median
a. visual feedback for a successful command	0	0	1	0	3	8	0	Very Adequate (2)
b. visual feedback for an error condition	0	0	4	5	1	2	0	Neutral (0)
c. auditory feedback for a successful command	0	0	3	0	1	7	1	Very Adequate (2)
d. auditory feedback for an error condition	0	0	4	3	2	3	0	Neutral (0)

M.2.1.4 Question 4

Rate each type of feedback in terms of allowing you to trouble-shoot the system.

Non-Flying Pilots' Results								
Question	Completely Inadequate (-3)	Very Inadequate (-2)	Somewhat Inadequate (-1)	Neutral (0)	Somewhat Adequate (1)	Very Adequate (2)	Completely Adequate (3)	Median
a. visual feedback for a successful command	0	0	1	1	3	6	1	Very Adequate (2)
b. visual feedback for an error condition	0	0	3	6	1	2	0	Neutral (0)
c. auditory feedback for a successful command	0	1	2	1	2	5	1	Somewhat Adequate/ Very Adequate (1.5)
d. auditory feedback for an error condition	0	2	5	3	0	2	0	Somewhat Inadequate (-1)

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Flying Pilots' Results								
Question	Completely Inadequate (-3)	Very Inadequate (-2)	Somewhat Inadequate (-1)	Neutral (0)	Somewhat Adequate (1)	Very Adequate (2)	Completely Adequate (3)	Median
a. visual feedback for a successful command	0	0	2	3	1	5	1	Somewhat Adequate/ Very Adequate (1.5)
b. visual feedback for an error condition	0	1	2	3	4	2	0	Neutral/Somewhat Adequate (0.5)
c. auditory feedback for a successful command	0	0	4	2	1	5	0	Neutral/Somewhat Adequate (0.5)
d. auditory feedback for an error condition	0	0	4	5	2	1	0	Neutral (0)

M.2.1.5 Question 5

Rate the ease of dividing your attention between the DVI feedback display and the outside visual scene and vice versa.

Role	Very Difficult (-2)	Difficult (-1)	Borderline (0)	Easy (1)	Very easy (2)	Median
Non-Flying Pilot	0	1	1	6	4	Easy (1)
Flying Pilot	0	0	1	7	4	Easy (1)

M.2.1.6 Question 7

Rate your degree of agreement/disagreement with the following statement. "I felt the division of duties between the flying and non-flying pilot was appropriate".

Role	Strongly Disagree (-2)	Disagree (-1)	Neither Agree Nor Disagree (0)	Agree (1)	Strongly Agree (2)	Median
Non-Flying Pilot	0	3	1	7	1	Agree (1)
Flying Pilot	0	3	2	6	1	Agree (1)

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M.2.1.7 Question 8

Rate the frequency of occurrence of the following:

Non-Flying Pilots' Results						
Question	Rarely (1)	Occasionally (2)	Sometimes (3)	Frequently (4)	Often (5)	Median
a. The other crewmember tried to take over duties that had been assigned to me in the new CRM model.	10	0	1	1	0	Rarely (1)
b. I forgot which duties to perform in the new CRM model.	11	0	1	0	0	Rarely (1)

Flying Pilots' Results						
Question	Rarely (1)	Occasionally (2)	Sometimes (3)	Frequently (4)	Often (5)	Median
a. The other crewmember tried to take over duties that had been assigned to me in the new CRM model.	11	0	1	0	0	Rarely (1)
b. I forgot which duties to perform in the new CRM model.	7	5	0	0	0	Rarely (1)

M.3 FINAL QUESTIONNAIRE

M.3.1 Question 1

Rate how acceptable manual input and direct voice input are for the crew completing each of the following tasks.

Manual Input Ratings								
Question	Unacceptable Major Deficiencies (-3)	Quite Unacceptable (-2)	Fairly Unacceptable (-1)	Neutral (0)	Fairly Acceptable (1)	Quite Acceptable (2)	Totally Acceptable (3)	Median
a. setting Radio 1 to Preset 3	0	0	0	1	4	3	4	Quite Acceptable (2)
b. setting Radio 1 to 118.1	0	0	0	2	3	3	4	Quite Acceptable (2)

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Manual Input Ratings								
Question	Unacceptable Major Deficiencies (-3)	Quite Unacceptable (-2)	Fairly Unacceptable (-1)	Neutral (0)	Fairly Acceptable (1)	Quite Acceptable (2)	Totally Acceptable (3)	Median
c. setting Radio 3 to FM	0	0	2	2	3	3	2	Fairly Acceptable (1)
d setting long range source to Doppler	0	0	0	2	3	5	2	Quite Acceptable (2)
e. changing the 'Comm' header	0	0	0	0	2	6	4	Quite Acceptable (2)
f. activating a flight plan	0	0	0	1	5	4	2	Fairly Acceptable/Quite Acceptable (1.5)
g. activating the next leg of the flight plan	0	0	0	0	6	3	3	Fairly Acceptable/Quite Acceptable (1.5)
h. activating present position direct to waypoint 12	0	0	0	1	7	2	2	Fairly Acceptable (1)
i. activating present position direct to Home	0	0	1	2	7	0	2	Fairly Acceptable (1)
j. displaying the Comm Summary Page	0	0	0	2	3	3	4	Quite Acceptable (2)
k. displaying the flight plan route	0	0	0	1	7	1	3	Fairly Acceptable (1)
l. displaying the data for waypoint 7	0	0	0	3	5	3	1	Fairly Acceptable (1)
m. displaying present position	0	0	0	0	1	7	4	Quite Acceptable (2)
n. switching present position	0	0	0	1	2	5	4	Quite Acceptable (2)
o. monitoring Nav A	0	0	0	2	3	4	3	Quite Acceptable (2)
p. monitoring all radios	0	0	2	4	3	2	1	Neutral/ Fairly Acceptable (0.5)

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Manual Input Ratings								
Question	Unacceptable Major Deficiencies (-3)	Quite Unacceptable (-2)	Fairly Unacceptable (-1)	Neutral (0)	Fairly Acceptable (1)	Quite Acceptable (2)	Totally Acceptable (3)	Median
q. stopping monitoring all radios	0	0	3	2	3	2	2	Fairly Acceptable (1)
r. isolating to Radio 3	0	0	1	5	3	2	1	Neutral/ Fairly Acceptable (0.5)
s. calculating endurance and range	0	0	2	5	4	0	1	Neutral (0)

Direct Voice Input Ratings								
Question	Unacceptable Major Deficiencies (-3)	Quite Unacceptable (-2)	Fairly Unacceptable (-1)	Neutral (0)	Fairly Acceptable (1)	Quite Acceptable (2)	Totally Acceptable (3)	Median
a. setting Radio 1 to Preset 3	0	0	0	1	2	6	3	Quite Acceptable (2)
b. setting Radio 1 to 118.1	0	0	0	2	2	6	2	Quite Acceptable (2)
c. setting Radio 3 to FM	0	0	0	4	1	6	1	Quite Acceptable (2)
d. setting long range source to Doppler	0	0	0	2	6	2	2	Fairly Acceptable (1)
e. changing the 'Comm' header	0	0	1	2	1	7	1	Quite Acceptable (2)
f. activating a flight plan	0	0	0	2	2	7	1	Quite Acceptable (2)
g. activating the next leg of the flight plan	0	0	0	1	4	5	2	Quite Acceptable (2)
h. activating present position direct to waypoint 12	0	0	0	1	2	7	2	Quite Acceptable (2)

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M.10

BAE SYSTEMS CANADA INC
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Direct Voice Input Ratings

Question	Unacceptable Major Deficiencies (-3)	Quite Unacceptable (-2)	Fairly Unacceptable (-1)	Neutral (0)	Fairly Acceptable (1)	Quite Acceptable (2)	Totally Acceptable (3)	Median
i. activating present position direct to Home	0	0	0	0	2	8	2	Quite Acceptable (2)
j. displaying the Comm Summary Page	0	0	0	2	3	4	3	Quite Acceptable (2)
k. displaying the flight plan route	0	0	1	2	3	5	1	Fairly Acceptable/Quite Acceptable (1.5)
l. displaying the data for waypoint 7	0	0	0	3	0	7	2	Quite Acceptable (2)
m. displaying present position	0	0	0	1	1	6	4	Quite Acceptable (2)
n. switching present position	0	0	0	1	2	4	5	Quite Acceptable (2)
o. monitoring Nav A	0	0	0	2	2	4	4	Quite Acceptable (2)
p. monitoring all radios	0	0	0	1	1	7	3	Quite Acceptable (2)
q. stopping monitoring all radios	0	0	0	1	0	8	3	Quite Acceptable (2)
r. isolating to Radio 3	0	0	0	0	4	4	4	Quite Acceptable (2)
s. calculating endurance and range	0	0	0	0	2	6	4	Quite Acceptable (2)

M.11

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M.3.2 Question 2

Rate which input mode you would prefer for each of the following tasks.

Question	Always MI (-2)	Usually MI (-1)	Equally MI & DVI (0)	Usually DVI (1)	Always DVI (2)	Median
a. setting Radio 1 to Preset 3	0	1	5	5	1	Usually DVI (1)
b. setting Radio 1 to 118.1	0	3	0	8	1	Usually DVI (1)
c. setting Radio 3 to FM	0	2	2	7	1	Usually DVI (1)
d. setting long range source to Doppler	1	2	4	5	0	Equally MI & DVI/Usually DVI (0.5)
e. changing the 'Comm' header	2	2	5	3	0	Equally MI & DVI (0)
f. activating a flight plan	1	0	3	5	3	Usually DVI (1)
g. activating the next leg of the flight plan	1	1	1	6	3	Usually DVI (1)
h. activating present position direct to waypoint 12	0	1	1	8	2	Usually DVI (1)
i. activating present position direct to Home	0	0	1	7	4	Usually DVI (1)
j. displaying the Comm Summary Page	1	2	4	3	2	Equally MI & DVI (0)
k. displaying the flight plan route	0	2	4	5	1	Equally MI & DVI/ Usually DVI (0.5)
l. displaying the data for waypoint 7	0	1	3	6	2	Usually DVI (1)
m. displaying present position	1	0	4	5	2	Usually DVI (1)
n. switching present position	2	1	0	7	2	Usually DVI (1)
o. monitoring Nav A	0	0	4	6	2	Usually DVI (1)
p. monitoring all radios	0	0	2	4	6	Usually DVI/Always DVI (1.5)
q. stopping monitoring all radios	0	0	2	3	7	Always DVI (2)
r. isolating to Radio 3	0	0	1	7	4	Usually DVI (1)
s. calculating endurance and range	0	0	3	5	4	Usually DVI (1)

M.12

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M.3.3 Question 3

Two criteria were used to determine inclusion of DVI commands, please rate their importance.

Criteria	Very Unimportant (-3)	Quite Unimportant (-2)	Fairly Unimportant (-1)	Neutral (0)	Fairly Important (1)	Quite Important (2)	Very Important (3)	Median
a. frequency of command use (included if high)	0	0	0	3	4	4	1	Fairly Important (1)
b. potential to lower workload	0	0	0	0	3	7	2	Quite Important (2)

M.3.4 Question 4

Two criteria were used to determine exclusion of DVI commands, please rate their importance.

Criteria	Very Unimportant (-3)	Quite Unimportant (-2)	Fairly Unimportant (-1)	Neutral (0)	Fairly Important (1)	Quite Important (2)	Very Important (3)	Median
a. complexity of task (excluded if high)	0	0	1	2	2	7	0	Quite Important (2)
b. potential for audio conflicts (exclusion if high)	0	0	0	0	2	7	3	Quite Important (2)

M.13

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M.3.5 Question 6

Rate the impact of DVI compared to MI, on the following:

Question	Substantial Degradation (-2)	Slight Degradation (-1)	No Change (0)	Slight Enhancement (1)	Substantial Enhancement (2)	Median
a. your awareness of spatial orientation	0	1	3	3	5	Slight Enhancement (1)
b. your awareness of the crew	2	5	4	1	0	Slight Degradation (-1)
c. your awareness of aircraft systems	0	5	6	1	0	No Change (0)
d. your awareness of the communication system	0	2	3	6	1	Slight Enhancement (1)
e. flight safety	1	2	2	3	4	Slight Enhancement (1)
f. mission effectiveness	0	0	4	7	1	Slight Enhancement (1)

M.3.6 Question 7

Compared to MI, rate the impact of DVI on your eyes out time.

Substantial Degradation (-2)	Slight Degradation (-1)	No Change (0)	Slight Enhancement (1)	Substantial Enhancement (2)	Median
0	0	1	5	6	Slight Enhancement/Substantial Enhancement (1.5)

M.14

31 Aug 00

ANNEX N
WRITTEN RESPONSES TO QUESTIONNAIRES

31 Aug 00

ANNEX N - WRITTEN RESPONSES TO QUESTIONNAIRES

N.1 MANUAL QUESTIONNAIRE

N.1.1 Question 6

Please list any additional comments you have about the feedback for manual input.

N.1.1.1 While acting as NFP

- a. P(1, 4, 10): requires looking down a lot, away from outside and map.
- b. P(4, 5): lot of time spent entering and confirming data.
- c. P(7): often reliant on FP's CDU, which removes it from FP's use.
- d. P(9): very use to the system, and know what to expect from it even though it may not be the most efficient.

N.1.1.2 While acting as FP

- a. P(7, 8, 10, 12): have been trained to minimize input to CDU, only occasional glances were made.
- b. P(4): bearing pointer and ME are all that is required (would be nice if they were positioned higher).

N.1.2 Question 7

Is the current ACD implementation of the CDU a good facsimile of the CDU in the Griffon ? (Yes/ No) Explain.

- a. P(1-12): all said yes, in general. Several exceptions were noted, as listed below.
- b. P(2, 4, 5, 6, 8, 9, 11, 12): time response when entering data is a little slower than the CDU in the Griffon.
- c. P(11): had difficulty inputting manual frequencies in preset boxes, had to re-input frequencies occasionally.
- d. P(3): when trying to select HF radio (radio #5) to standby, the settings would only toggle between duplex and simplex.
- e. P(10): 'previous' button didn't work.

N.1.3 Question 8

Please provide any thoughts you have on the CRM in the Griffon cockpit.

- a. P(1): current CRM ensures that one pilot is looking outside at all times.
- b. P(2): since both pilots are monitoring the same radios, the FP should be able to proceed with tasking (i.e., flying to the recce start point), without direction from the NFP, allowing the NFP to set-up the CDU.
- c. P(3): with no FE present, scenario is rather artificial as FEs do perform some cockpit tasks during high workload situations.
- d. P(4): current CDU set-up requires constant head-down and distinct division of tasks between FP and NFP. It makes CRM difficult due to dissimilar tasks of each pilot: FP mostly looking outside, NFP mostly looking inside while explaining what they are each doing. This is very time consuming.
- e. P(5, 6, 10, 12): for the purpose of this experiment the NFP is conducting all aspects of CDU function. In reality, FP can operate a radio when the workload of the NFP is excessive.
- f. P(8): as NFP certainly felt very busy during the mission, and realized that I missed a few calls and experienced a feeling of getting behind on tasks.
- g. P(9): the CRM in the Griffon is quite effective. A crew that understands their responsibilities can work very well together in stressful situations. Communication is key and the division of tasks between the FP, NFP, and FE can greatly facilitate the ease of a mission.

N.2 DVI QUESTIONNAIRE

N.2.1 Question 6

Please list any additional comments you have about the feedback for the DVI system.

- a. P(1, 2, 8, 10): Good system, DVI will be a very useful tool as it allows both pilots to focus their attention outside the cockpit, and on the map.
- b. P(1, 3, 4, 9): system should give some indication as to why it is not responding (due to volume, syntax, etc.). For example if it had trouble recognizing a command, the visual feedback should be "not recognized".
- c. P(3, 4, 6): "happy" beep should be made more distinguishable from the "error" beep, could be missed under high workload situations, especially when visual focus is outside, and not on the feedback display.
- d. P(7): visual feedback should display the waypoint name and number simultaneously.

- e. P(9): workload was increased unnecessarily when the system interpreted what I was saying to the FP as a command, and changed my CDU page.
- f. P(9): did like the feedback (both visual and auditory) for successful input conditions.
- g. P(10): having the feedback display positioned right up front, makes it easy to look outside at the same time.
- h. P(10): should not hear the other pilots feedback beeps, they can be misinterpreted.
- i. P(11): last command received should be highlighted on the feedback display. Currently all three lines are the same.

N.2.2 Question 9

Please provide any other thoughts you have on CRM with DVI in the Griffon cockpit.

- a. P(1, 8, 10): will have to be re-adjusted to find a happy middle but once implemented, am sure it will enhance CRM.
- b. P(1, 2): since FP was in charge of changing own bearing pointer, NFP was hesitant in passing direction to the FP, just a matter of adjustment. Crew co-op must be maintained.
- c. P(2): DVI enables NFP, without looking down, to switch to both radios. There is thus no need to change current CRM. However, if NFP became over-tasked the FP could assume radio calls.
- d. P(3): CRM must be studied and revised further. The military is very 'anal' as to who is in control. Care must be taken to insure that a wall is not created between the crew.
- e. P(4): still uncertain what radio FE would monitor, both so as to know when to speak? The opportunity arises for no one to know what the other 2 are doing (channelized attention), possibly causing a decrease in situational awareness.
- f. P(4): requires essential use of Aviate, Navigate, and Communicate.
- g. P(4, 9): DVI CRM leaves little for NFP to do, as a result didn't feel useful or busy enough during transit and recce periods. In real life, would have advised the FP that I was taking one of the tasks temporarily.
- h. P(5): NFP (AMC) may not need to monitor zero if confident that the FP is competent enough to execute duties.

- i. P(9): as FP, while I was in a low manoeuvring phase of flight, I had to concentrate outside the cockpit and was slower at accomplishing my other CRM tasks, thus on one occasion the NFP took over one of my duties.
- j. P(10): multitasking is good for speed, but requires more communication between pilots. I believe that a well-trained crew with DVI will be able to perform many tasks in a small amount of time.
- k. P(11): conflicts may arise between talking to agencies, to crewmembers, and to DVI.

N.2.3 Question 10

Please list any individual DVI vocabulary words that you felt were awkward or difficult to say, use, or remember during the mission you just performed.

- a. P(1, 11): no problems, said wrong words a few times but was able to correct myself quickly. This like any other thing will become second nature with practice.
- b. P(2): 'Activate' vs. 'Start', 'Set' vs. 'Switch', 'Set' vs. 'Display' (i.e., header).
- c. P(3, 11, 12): DVI should be more error tolerant of the use of a word in its singular vs. plural form (e.g., comm. for comms).
- d. P(7): To avoid having to check the status of the system visually, the system if activated, should ignore any further utterances of the word 'computer'.

N.2.4 Question 11

Please list any DVI commands that you felt were awkward or difficult to say, use or remember during the mission you just completed.

- a. P(2, 11): said Start Flight Plan Next; kept forgetting to use activate.
- b. P(2, 4, 11): difficult to remember to 'set' radio frequency instead of 'switch' to a new frequency.
- c. P(4, 11): 'Activate Present Position Direct to Waypoint X' is too long to say, instead should be shortened to 'Activate Direct to X'.
- d. System uses 'Long Range Source' as initial words of command. Would recommend 'Long Range Nav' or 'Navigation Source'.

- e. P(9): could accomplish some tasks with different commands, which I liked. To squawk ident I said 'Set IFF 1200', and to display the Comm. Summary Page I said 'Set Comm. Page', and it also worked.
- f. Display Flt Plan Route.

N.2.5 Question 12

Please list any words or phrases that the DVI system had difficulty recognizing.

- a. P(1): Would not recognize 'PPOS Direct to WP 10 or 14' had to use the name of the waypoint instead (e.g., Vee).
- b. P(2): set radio 2 120.7, interpreted as set radio 1 210.7.
- c. P(3): Three recognized as Creek.
- d. P(4): Display quick-review waypoints, and display quick-review comms took several attempts.
- e. P(3, 4): One of the waypoints was named 'point'. System would not recognize 'PPOS Direct to Waypoint Point'.
- f. P(9, 11): 'Next' was recognized when saying 'yes' to the other pilot.
- g. P(9, 12): set radio 1 118.1 had bad recognition.
- h. P(10): confusion between 'four' and 'far', and '2' and '7' (e.g., set radio 1 120.7 was recognized as 170.7).
- i. P(12): point worked better than decimal.

N.3 FINAL QUESTIONNAIRE

N.3.1 Question 5

Please list any other criteria you feel should be used when determining if a task should be implemented with DVI.

- a. P(3): if a command is embedded way down the menu hierarchy, it should be used with DVI.
- b. P(4, 11): Is it easier to do with DVI than MI? E.g., # of steps required to complete task.
- c. P(7): whether or not in a critical phase of flight unintentional or ill thought out inputs could endanger the flight.

- d. P(10): even if the task is complex, we should try to find a way to make it easier using DVI.

N.3.2 Question 8

Please list any additional functionality that should be made available for a future DVI implementation in the Griffon.

- a. P(3): any or all functions in the AMS capable of MI should be able to be implemented by DVI unless further workload studies show that there is no advantage to doing so.
- b. P(4): interface with a map display, so you can PPOS direct to an unidentified waypoint (i.e., location by touch screen).
- c. P(5): isolate me to ICS, otherwise we have to do it in 2 separate operations, i.e., isolate me to radio 1, and stop monitoring radio 1.
- d. P(7): bearing and range calculations, relative waypoint calculations, and entry of a waypoint list.
- e. P(7): on entering calculations with more than one parameter, if a mistake was made, I was forced to start all over. I would suggest 'correction' to clear a parameter.
- f. P(9, 10): ability to create new waypoint, allowing the pilot to enter grids using DVI (currently one of the most time consuming tasks on the CDU).
- g. P(9, 10): a new function that allows you to go back to the last frequency you had on your radio (e.g., set radio 1 previous).
- h. P(10): alternate function replacing the alternate button on the comm. Summary page. (E.g., set radio 1 to alternate, radio 1 switches to the pre-programmed preset loaded on the DTC. If no alternate found, then error message appears (used frequently in Bosnia).
- i. P(11): Hover Display, Name New Storepoint, Init. Page, Load Cartridge, and Save Data.

N.3.3 Question 9a/b

Which of the following approaches do you think would result in the most usable DVI system:

- a. 4th crewmember
- b. private
- c. Hybrid

Please explain your choice.

- a. P(1-12): #3
- b. P(1, 4, 5, 9): not all things need to be passed to all crewmembers and the option for private allows less comms traffic internally during peak phases. The crewmember can inform the others of the input when comms traffic permits. It is also important at times that all members are aware of changes being made (to maintain SA etc.).
- c. P(2, 11): some commands can be implemented in private to allow other crewmember to concentrate on their task without distraction.
- d. P(3, 10, 12): team members usually need to know what the other crewmembers are doing, private mode should be reserved to non-essential tasks (e.g., setting header comm.).
- e. P(7): we do not another switch on the cyclic. There is a history of button confusion with this control (i.e. inadvertent load release). As a result I suggest something other than the cyclic button for this purpose.
- f. P(8): We already isolate comms as part of certain SMM tasks this is no different.

N.3.4 Question 10 b)

Please list any other feedback alternatives you feel should be considered for the DVI system.

P(1-12): None

N.3.5 Question 11

Do you feel that a DVI command (not display) should result in a page change on the CDU? (Yes/No) Explain.

- a. P(1, 11) Yes, to allow aircrew to quickly visually confirm the data, but the CDU should return to the default page (page used last) after a few seconds.
- b. P(2, 4, 6, 10, 12): No, the DVI display is sufficient for the majority of commands. We often retain one particular page on the CDU and if it were constantly changed due to DVI, it would necessitate a return command.
- c. P(3, 5): No, the advantage with DVI is that you can multitask by making changes with DVI while still maintaining an important page on the CDU such as the Flt Plan page.
- d. P(7, 9): No, having the ability to perform simple tasks without working through a long series of pages and key touches is the main advantage of the

DVI system. As long as the visual display confirms the command, there should be no need to revert to the page. The option is always there to display a new page.

N.3.6 Question 12

In your view, is it worthwhile to pursue a DVI system for the CH146 Griffon?
(Yes/No) Explain.

- a. P(1, 2, 4, 11, 12): Yes, with proper implementation of system and CRM, it would allow both pilots to keep eyes out.
- b. P(1): Yes, tasks can be accomplished a lot quicker, which in turn will allow more time to remain focused on the mission.
- c. P(3): Yes, the battlefield is getting busier all the time. Anything that will equitably share workload is welcome. However, DVI is not a panacea. It should be studied more closely.
- d. P(4): Yes, as an alternative to the current set-up, but exploring other ways to reduce head-down may be beneficial. Perhaps a combination of DVI and a HUD? Ultimately head-down in a low level environment is dangerous and undesirable.
- e. P(5): Yes, as long as the choice to use it is primarily down to the user. I find my results are better for DVI than MI as long as the new crew duties are identified.
- f. P(6): Yes, if it remains easy to use.
- g. P(7): Yes, particularly for CH146, as CDU placement is so poor.
- h. P(9): Yes, overall it can enhance CRM as we have seen during this trial.
- i. P(9): Yes, I would say that in my opinion DVI would be beneficial to the Griffon, if it were not for the expense.
- j. P(10): Yes, we saw that DVI can reduce workload or increase the speed at which the operator can perform tasks under high intensity missions. However, we don't fly high intensity missions very often. Perhaps this amount will increase as we get more involved in peacekeeping, or develop new roles for the Griffon such as reconnaissance with the FLIR system.
- k. P(11): Yes, with display improvements the advantage of always looking up will be great, but too much chatter may be just as bad as taking a quick look at the CDU.

N.4 ADDITIONAL COMMENTS REGARDING TESTING FACILITY

- a. P(3): slip indicator (the ball) does not respond realistically, or at least to what I am use to in the slow speed and hovering flight regimes.
- b. P(3): because there is no depth perception afforded by a 2-D presentation of a 3-D scene, it is difficult to assess/gauge distances. Greater fidelity of the visual scene would definitely heighten the realism of the experience.
- c. P(7): deceleration to a contact is very unrealistic in my view. I noted contact reports to be higher than normal effort as a result.
- d. P(9): as the FP, my tasks on this flight were compounded by difficulties I had manoeuvring the ACD. I feel that juggling the tasks would not be as difficult in real life, where I am use to the controls and the machine's behaviour.
- e. P(10): console lighting would be a good addition to the ACD, as it gets quite dark at times.
- f. P(1, 2, 11, 12): there was a lot of feedback from ICS, making it difficult to hear agencies and crew.

**ANNEX O
EVENT CUT-OFF TIMES**

ANNEX O - EVENT CUT-OFF TIMES**O.1 EXPERIMENT 1 - EVENT RELATED CUTOFF TIMES**

Event #1 - Start-Up to Take-Off				
Crew	Manual Trial #1	Manual Trial #2	DVI Trial #1	DVI Trial #2
Crew 1	0.00 - 119.13	0.00 - 151.83	0.00 - 189.21	0.00 - 122.92
Crew 2	0.00 - 141.20	0.00 - 150.45	0.00 - 145.39	0.00 - 130.14
Crew 3	0.00 - 96.00	0.00 - 149.00	0.00 - 156.00	0.00 - 126.00
Crew 4	0.00 - 203.00	0.00 - 190.00	0.00 - 167.00	0.00 - 263.00
Crew 5	0.00 - 136.00	0.00 - 163.00	0.00 - 92.00	0.00 - 133.00
Crew 6	0.00 - 144.00	0.00 - 112.00	0.00 - 320.00	0.00 - 128.00

Event #2 - Take-Off to Start Recce #1				
Crew	Manual Trial #1	Manual Trial #2	DVI Trial #1	DVI Trial #2
Crew 1	119.13 - 189.61	151.83 - 217.59	189.21 - 327.50	122.92 - 173.25
Crew 2	141.20 - 219.83	150.45 - 366.89	145.39 - 223.59	130.14 - 266.42
Crew 3	96.00 - 145.00	149.00 - 209.00	156.00 - 304.00	126.00 - 181.00
Crew 4	203.00 - 264.00	190.00 - 348.00	167.00 - 223.00	263.00 - 323.00
Crew 5	136.00 - 192.00	163.00 - 219.00	92.00 - 255.00	133.00 - 202.00
Crew 6	144.00 - 457.00	112.00 - 298.00	320.00 - 375.00	128.00 - 181.00

Event #3 - Start Recce #1 to Complete Recce #1				
Crew	Manual Trial #1	Manual Trial #2	DVI Trial #1	DVI Trial #2
Crew 1	189.61 - 462.85	217.59 - 547.44	327.50 - 639.41	173.25 - 447.69
Crew 2	219.83 - 529.96	366.89 - 617.49	223.59 - 486.71	266.42 - 467.70
Crew 3	145.00 - 400.00	209.00 - 497.00	304.00 - 524.00	181.00 - 470.00
Crew 4	264.00 - 596.00	348.00 - 679.00	223.00 - 472.00	323.00 - 725.00
Crew 5	192.00 - 523.00	219.00 - 765.00	255.00 - 500.00	202.00 - 529.00
Crew 6	457.00 - 954.00	298.00 - 513.00	375.00 - 632.00	181.00 - 401.00

Event #4 - Complete Recce #1 to Start Recce #2				
Crew	Manual Trial #1	Manual Trial #2	DVI Trial #1	DVI Trial #2
Crew 1	462.85 - 760.89	547.44 - 670.75	639.41 - 744.55	447.69 - 600.17
Crew 2	529.96 - 826.51	617.49 - 917.64	486.71 - 622.36	467.70 - 581.61
Crew 3	400.00 - 543.00	497.00 - 559.00	524.00 - 723.00	470.00 - 567.00
Crew 4	596.00 - 804.00	679.00 - 910.00	472.00 - 560.00	725.00 - 862.00
Crew 5	523.00 - 712.00	765.00 - 981.00	500.00 - 718.00	529.00 - 678.00
Crew 6	954.00 - 1129.00	513.00 - 729.00	632.00 - 696.00	401.00 - 548.00

Event #5 - Start Recce #2 to Complete Recce #2				
Crew	Manual Trial #1	Manual Trial #2	DVI Trial #1	DVI Trial #2
Crew 1	760.89 - N/A	670.75 - 849.61	744.55 - 1020.07	600.17 - 1024.42
Crew 2	826.51 - 1221.90	917.64 - 1730.12	622.36 - 868.88	581.61 - 905.45
Crew 3	543.00 - 787.00	559.00 - 918.00	723.00 - 1213.00	567.00 - 880.00
Crew 4	804.00 - 1056.00	910.00 - 1218.00	560.00 - 844.00	862.00 - 1087.00
Crew 5	712.00 - 1003.00	981.00 - 1238.00	718.00 - 988.00	678.00 - 1019.00
Crew 6	1129.00 - 1395.00	729.00 - 905.00	696.00 - 952.00	548.00 - 779.00

Sub-event #1 - 1 st Contact Visual to Sending Contact Report				
Crew	Manual Trial #1	Manual Trial #2	DVI Trial #1	DVI Trial #2
Crew 1	300.62 - 365.92	N/A	403.99 - 544.87	280.50 - 307.10
Crew 2	322.13 - 412.76	451.98 - 512.91	292.92 - 355.44	324.54 - 382.50
Crew 3	251.00 - 308.00	286.00 - 374.00	378.00 - 439.00	264.00 - 339.00
Crew 4	364.00 - 458.00	473.00 - 597.00	284.00 - 340.00	546.00 - 661.00
Crew 5	326.00 - 414.00	345.00 - 501.00	357.00 - 722.00	273.00 - 413.00
Crew 6	553.00 - 833.00	379.00 - 460.00	427.00 - 517.00	254.00 - 331.00

Sub-event #2 - 2 nd Contact Visual to Sending Contact Report				
Crew	Manual Trial #1	Manual Trial #2	DVI Trial #1	DVI Trial #2
Crew 1	853.23 - N/A	N/A	793.77 - 832.65	840.66 - 863.38
Crew 2	1075.93 - 1186.94	1552.82 - 1624.43	679.81 - 735.46	718.06 - 832.73
Crew 3	630.00 - 722.00	723.00 - 794.00	1155.00 - 1190.00	770.00 - 835.00
Crew 4	932.00 - 967.00	1084.00 - 1151.00	655.00 - 701.00	958.00 - 1041.00
Crew 5	852.00 - 926.00	1022.00 - 1100.00	856.00 - 907.00	855.00 - 902.00
Crew 6	1288.00 - 1334.00	839.00 - 856.00	765.00 - 843.00	625.00 - 710.00

Sub-event #3 - Re-tasked to Finished Entering New Flight Plan				
Crew	Manual Trial #1	Manual Trial #2	DVI Trial #1	DVI Trial #2
Crew 1	466.88 - 743.01	544.17 - 658.80	642.83 - 735.16	432.53 - 636.48
Crew 2	517.05 - 644.66	609.04 - 765.00	489.99 - 603.76	478.70 - 515.57
Crew 3	432.00 - 475.20	485.00 - 523.17	528.00 - 641.21	445.00 - 472.03
Crew 4	588.00 - 686.16	687.00 - 811.58	442.00 - 486.55	739.00 - 805.43
Crew 5	304.00 - 517.44	768.00 - 984.82	519.00 - 600.96	519.00 - 558.39
Crew 6	934.00 - 1073.17	524.00 - 612.37	604.00 - 628.38	412.00 - 464.90

Sub-event #4 - Request for Endurance and Range to Compute				
Crew	Manual Trial #1	Manual Trial #2	DVI Trial #1	DVI Trial #2
Crew 1	N/A	868.65 – 884.19	1046.00 – 1177.51	1056.14 – 1129.25
Crew 2	1444.32 – 1461.84	1723.43 – 1755.39	930.00 – 1008.03	963.00 – 1020.42
Crew 3	839.00 – 863.93	940.00 – 963.03	1278.00 – 1326.48	960.00 – 1001.96
Crew 4	1180.00 – 1192.15	1273.00 – 1294.23	855.00 – 978.08	1146.00 – 1267.22
Crew 5	1078.00 – 1104.41	1273.00 – 1295.81	1031.00 – 1083.27	1097.00 – 1120.00
Crew 6	1520.00 – 1537.77	938.00 – 960.16	988.00 – 1108.45	864.00 – 901.91

0.2 EXPERIMENT 2 - EVENT RELATED CUTOFF TIMES

Event #1 – Start-Up to Take-Off		
Crew	Manual Detection	DVI Detection
Crew 1	0.00 – 156.58	0.00 – 169.87
Crew 2	0.00 – 99.64	0.00 – 140.41
Crew 3	0.00 – 104.00	0.00 – 139.00
Crew 4	0.00 – 183.00	0.00 – 130.00
Crew 5	0.00 – 135.00	0.00 – 79.00
Crew 6	0.00 – 126.00	0.00 – 188.00

Event #2 – Take-Off to Start Recce #1		
Crew	Manual Detection	DVI Detection
Crew 1	156.58 – 230.69	169.87 – 286.61
Crew 2	99.64 – 435.52	140.41 – 248.23
Crew 3	104.00 – 196.00	139.00 – 233.00
Crew 4	183.00 – 272.00	130.00 – 218.00
Crew 5	135.00 – 270.00	79.00 – 178.00
Crew 6	126.00 – 242.00	188.00 – 258.00

Event #3 - Start Recce #1 to Complete Recce #1		
Crew	Manual Detection	DVI Detection
Crew 1	230.69 – 427.92	286.61 – 561.21
Crew 2	435.52 – 696.60	248.23 – 477.46
Crew 3	196.00 – 389.00	233.00 – 548.00
Crew 4	272.00 – 661.00	218.00 – 409.00
Crew 5	270.00 – 448.00	178.00 – 419.00
Crew 6	242.00 – 508.00	258.00 – 431.00

Event #4 - Complete Recce #1 to Start Recce #2		
Crew	Manual Detection	DVI Detection
Crew 1	427.92 - 471.48	561.21 - 666.12
Crew 2	696.60 - 1037.19	477.46 - 654.94
Crew 3	389.00 - 453.00	548.00 - 590.00
Crew 4	661.00 - 690.00	409.00 - 598.00
Crew 5	448.00 - 594.00	419.00 - 475.00
Crew 6	508.00 - 604.00	431.00 - 505.00

Event #5 - Start Recce #2 to Complete Recce #2		
Crew	Manual Detection	DVI Detection
Crew 1	471.48 - 818.70	666.12 - 1026.63
Crew 2	1037.19 - N/A	654.94 - 991.72
Crew 3	453.00 - 730.00	590.00 - 926.00
Crew 4	690.00 - 948.00	598.00 - 875.00
Crew 5	594.00 - 948.00	475.00 - 775.00
Crew 6	604.00 - 1015.00	505.00 - 744.00

Sub-event #1 - 1 st Contact Visual to Sending Contact Report		
Crew	Manual Detection	DVI Detection
Crew 1	277.63 - 334.40	337.33 - 400.66
Crew 2	515.91 - 548.61	314.13 - 375.25
Crew 3	251.00 - 288.00	277.00 - 325.00
Crew 4	313.00 - 371.00	272.00 - 341.00
Crew 5	309.00 - 378.00	235.00 - 278.00
Crew 6	291.00 - 320.00	314.00 - 360.00

Sub-event #2 - 2 nd Contact Visual to Sending Contact Report		
Crew	Manual Detection	DVI Detection
Crew 1	635.51 - 688.60	926.04 - 937.35
Crew 2	1136.15 - N/A	774.40 - 860.00
Crew 3	567.00 - 599.00	783.00 - 848.00
Crew 4	814.00 - 880.00	736.00 - 776.00
Crew 5	782.00 - 838.00	643.00 - 692.00
Crew 6	702.00 - 890.00	644.00 - 680.00

Sub-event #3 - Re-tasked to Finished Entering New Flight Plan		
Crew	Manual Detection	DVI Detection
Crew 1	419.26 - 505.70	565.26 - 655.90
Crew 2	711.94 - 919.71	513.69 - 565.53
Crew 3	379.00 - 444.73	525.00 - 550.33
Crew 4	514.00 - 659.37	416.00 - 467.74
Crew 5	455.00 - 533.95	385.00 - 446.35
Crew 6	469.00 - 572.31	423.00 - 450.49

Sub-event #4 - Request for Endurance and Range to Compute		
Crew	Manual Detection	DVI Detection
Crew 1	854.38 - 870.01	1048.24 - 1073.20
Crew 2	N/A	1032.88 - 1051.31
Crew 3	817.00 - 824.90	980.00 - 1007.72
Crew 4	1040.00 - 1061.20	888.00 - 944.18
Crew 5	983.00 - 1029.24	798.00 - 824.34
Crew 6	1048.00 - 1107.49	840.00 - 860.11

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14 ABSTRACT

(U) The Canadian Forces Utility Tactical Transport Helicopter is a modern land aviation aircraft which is used in numerous complex roles. The core of the CH146 Griffon avionics system architecture is a BAE SYSTEMS CANADA INC (BSC) Control and Display Unit (CDU). The location and method of operation of the CDU requires extended heads-down operation by the pilot in some circumstances, which has been found to have flight safety implications in the tactical helicopter environment, particularly in bad weather or when using Night Vision Goggles (NVGs). One technology that shows substantial promise to address this issue is Direct Voice Input (DVI). DVI permits the control of equipment using voice commands, and has the potential to greatly reduce the amount of time that the pilot has to direct his visual attention to controls and displays in the cockpit.

BSC was tasked by the Defence and Civil Institute of Environmental Medicine (DCIEM) to develop an operationally suitable Operator Interface (OI) for the CH146 Griffon. Additionally, BSC was to perform, in conjunction with the National Research Council (NRC), an assessment of a speech recognition system during operational type missions in a Bell 412 helicopter.

An OI (syntax and feedback) was developed. A literature review and site visits to DVI research facilities provided the foundation for the OI development. The proposed feedback is an audio-alerting tone supplemented by a small text-based display.

Two experiments were conducted in the BSC Aircraft Crewstation Demonstrator comparing the existing cockpit and crew configuration with a DVI-equipped cockpit.

Subjective and objective data showed that the DVI system reduced the workload of the Non Flying Pilot (NFP) and reduced the amount of time that the NFP was required to look down into the cockpit. The results also showed that the Flying Pilot (FP) allocated attention toward the DVI system, thus providing the FP with additional information relating to aircraft systems, having a negative impact on the FP's performance on other tasks. It was concluded that a DVI system would have the potential to enhance flight safety and mission performance for crew in the CH146 Griffon.

A Verbex™ speech recognizer was installed in the NRC Bell 412 helicopter to assess system performance under ambient helicopter noise. Participants flew the helicopter under four flight profiles while reading prompts into the speech recognizer from a small liquid crystal display mounted under the glare shield. The overall phrase error rate for the system was 6.4%.

Further research addressing the human factors issues should be conducted to understand the interaction between the FP and the DVI system in both the modified Crew Resource Management (CRM) implemented in the OI evaluation and the current Griffon CRM. Alternative feedback methods should be explored as well as the syntax optimization. To support the pre-production system development, alternate speech recognizers should be assessed in the challenging helicopter environment to select the technology best suited to the application.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) Control Display Unit; Night Vision Goggles; Direct Voice Input; Operator Interface; Aircraft Crewstation Demonstrator; Crew Resource Management; Perceptual Control Theory; Visual, Auditory, Cognitive and Psychomotor

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